One cannot but be in awe when [one] contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries to merely comprehend a little of this mystery each day. Never lose a holy curiosity.

Albert Einstein

I went to the woods because I wished to live deliberately, to front only the essential facts of life, and see if I could learn what it had to teach, and not, when I came to die, discover that I had not lived.

Henry David Thoreau, *Walden*, 1854

Attitude is altitude.

Julius Erving

We end, I think, at what might be called the standard paradox of the twentieth century: our tools are better than we are, and grow better faster than we do. They suffice to crack the atom, to command the tides. But they do not suffice for the oldest task in human history: to live on a piece of land without spoiling it.

Aldo Leopold

He sweeps along the margins of the fields, through the woods, and by the edges of ponds and rivers, with such speed as to enable him to seize his prey by merely deviating a few yards from his course, assisting himself on such occasions by his long tail, which, like a rudder, he throws to the right or left, upwards or downwards, to check his progress, or enable him suddenly to alter his course. At times he passes like a meteor through the underwood, where he secures squirrels and hares with ease. Should a flock of Wild Pigeons pass him on these predatory excursions, he immediately gives chase, soon overtakes them, and forcing his way into the very centre of the flock, scatters them in confusion, when you may see him emerging with a bird in his talons, and diving towards the depth of the forest to feed upon his victim.

Audubon (1840)

University of Alberta

Northern Goshawk (*Accipiter gentilis*) Habitat Characterization in central Alberta

by

Warren Wesley Schaffer ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Masters of Science

in

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Northern Goshawk (*Accipiter gentilis*) Habitat Characterization in Central Alberta submitted by Warren Wesley Schaffer in partial fulfillment of the requirements for the degree of Masters of Science in Wildlife Ecology and Management.

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Date: April 3, 1998

To my family
Jason, Adam, Mom and Pap

ABSTRACT

Northern Goshawk (*Accipiter gentilis*) nesting habitat selection and prey use were investigated in central Alberta. Nests were typically located in the lower portion of the crown, on a primary branch fork of large *Populus* trees (mean diameter = 30.0 cm, mean height = 21.9 m). Nesting stands had multiple canopy layers, canopy gaps, large standing and fallen dead trees, and multiple ages of trees that characterize mature seral stages of vegetation. Northern Goshawks did not exhibit a preference for nest site aspect ($0.50>P>0.20$). The nest sites and contrast sites were not significantly different ($\alpha=0.00625$) based on eight vegetation variables (average height of overstory, average DBH, total canopy closure, volume of downed woody debris, live basal area, total herb coverage, total shrub coverage, total basal area) and in the proportion of live and dead stems in different diameter classes (Pearson Chi-square = 7.2049, $0.75>P>0.50$). The majority of the Northern Goshawk diet was composed of prey species from the larger size classes, primarily Snowshoe Hare (*Lepus americanus*), Red Squirrel (*Tamiasciurus hudsonicus*), Ruffed Grouse (*Bonasa umbellus*), Mallard (*Anas platyrhynchos*), and Richardson's Ground Squirrel (*Spermophilus richardsonii*). In west-central Alberta, an interspersion of forests with different age classes would provide areas where prey populations will thrive (younger age classes), adjacent to areas where prey are available to the Northern Goshawks (older age classes). Northern Goshawk habitat management should include efforts to: conserve active nests; conserve older forests for nesting and foraging habitat; educate resource managers and forestry workers; and conduct further research.

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1.0 Introduction

1.1 STUDY BACKGROUND

In recent years, increased attention has been focused on conservation of biological diversity during forest harvesting operations (Probst and Crow 1991, Spies *et al.* 1991, Ledig 1993, Thompson *et al.* 1993, Thompson and Welsh 1993, Kimmins 1995). Large birds of prey typically occupy a top position in the food-web of a locality (Graham *et al.* 1994, Burnham and Cade 1995). These birds are good candidates for studies aimed at increased understanding of ecological processes (Burnham and Cade 1995). Management techniques that provide habitat for large birds of prey typically protect their ecological community (Franklin 1993, Graham *et al.* 1994, Reynolds 1995).

The Northern Goshawk (*Accipiter gentilis*) is the largest North American member of the genus *Accipiter* (Johnsgard 1990). Reverse sexual size dimorphism is exhibited by Northern Goshawks (adult male mean mass 0.9 kg, adult male wing length: 30 - 33 cm; adult female mass 1.1 kg, adult female wing length: 33 -37 cm) (Dunning 1984; Figure 1.1). The Northern Goshawk breeding range extends from northwestern Alaska, through to Labrador and Newfoundland, south to California, across the continental U.S. to Maryland into Mexico (Jones 1979). Northern Goshawks are partially migratory, with increased numbers of migrants in years of low prey abundance (Mueller *et al.* 1977). The winter range extends from western and central Alaska and British Columbia and southern Newfoundland to southern California, Mexico, Tennessee and the Virginias (Jones 1979).

Northern Goshawks (*Accipiter gentilis*) have been noted for their site fidelity (McGowan 1975, Reynolds and Wight 1978, Speiser and Bosakowski 1991), and their value as an indicator species for old seral stage forests (Bull and Hohmann 1994, Kirk 1995). Northern Goshawk breeding can be disturbed by human-related activities (i.e. logging, vehicular traffic) in the immediate vicinity of the nest that reduce the attentiveness of adult females (Grier and Fyfe 1988, Richardson and Miller 1997), or by changes to the nesting (Reynolds *et al.* 1982, Moore and Henny 1983, Kennedy 1988, McCarthy *et al.* 1989, Reynolds 1989, Crocker-Bedford 1990, Bosakowski and Speiser 1994) or foraging (Kirk 1995, Beier and Drennan 1997) habitats that make these habitats unsuitable for supporting their populations. In certain parts of their range, there has been an increased interest in Northern Goshawk ecology in order to formulate management prescriptions to directly conserve Northern Goshawk populations and their

associated wildlife populations (Reynolds 1983, Kennedy 1988, Lanier and Foss 1989, Reynolds *et al.* 1992, Reynolds 1995, Squires and Ruggiero 1996).

No intensive studies of Northern Goshawks have been undertaken in Alberta. Age of Northern Goshawk nestlings at time of banding, observations on the timing of fledging, direct observations of the movement of Northern Goshawks at the nests (N=33 nesting records, recorded 1952-1997; E. Pletz, T. Roper, E.T. Jones, J. Moore, R. Cromie, A. de Groot, personal communications, W. Schaffer, unpublished data), and documented information on the timing of chick development (Reynolds and Wight 1978, Jones 1979, Duncan and Kirk 1994) indicate that Northern Goshawks in central Alberta settle on territories in the first week of March, and remain in the post-fledging family area around the nest until late August. The current status of Northern Goshawk populations in the province of Alberta is unknown (Duncan and Kirk 1994, Alberta Environmental Protection 1996). Northern Goshawks appear on the Yellow List prepared by the province of Alberta (Alberta Environmental Protection 1996). The Yellow List denotes: "sensitive species that are not currently believed to be at risk, but may require special management to address concerns related to naturally low populations, limited provincial distributions, or demographic/life history features that make them vulnerable to human-related changes to the environment" (Alberta Environmental Protection 1996: 9).

1.2 THESIS DESCRIPTION

This thesis will present the findings of a study designed to describe the characteristics of nesting habitat and prey species used by Northern Goshawks during the breeding season in central Alberta based on original observation, consultation with scientific literature, and local knowledge. In chapter 2, I will characterize the nesting habitat used by Northern Goshawks at the scale of nest tree and nest stand, and will examine selection of Northern Goshawk nesting areas within deciduous-dominated (*Populus*-dominated) mixedwood stands. In chapter 3, I will describe Northern Goshawk prey use in central Alberta, and will combine information on the microhabitat associations of Northern Goshawk prey species with information on Northern Goshawk foraging behaviour, in order to draw inferences on the characteristics of Northern Goshawk foraging environments in west-central Alberta. In chapter 4, I will use the findings of this thesis, and findings of other investigations of Northern Goshawk habitat use in order to suggest management recommendations for Northern Goshawks in central Alberta.

Figure 1.1 - Adult male (left) and adult female Northern Goshawks (photo courtesy of E. Pletz).

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2.0 Vegetation at Northern Goshawk (*Accipiter gentilis*) nest sites in central Alberta

2.1 INTRODUCTION

The nest site is the centre of the area for activity of breeding adult birds and offspring during the breeding season and the vegetation structure and composition around the nest site may influence reproductive success (Newton 1976, Cody 1981, Walsberg 1985, Reynolds 1989). A variety of factors can influence the choice of nest area selected by breeding birds including limitations of their morphology, presence of competitors, vegetation structure and composition, microclimate, imprinting on natal territory, and the influence of human populations (Klopfer and Ganzhorn 1985, Kennedy 1988, Bosakowski *et al.* 1992, Selas 1996). The selection of the nest area may operate in a hierarchical fashion, starting with the choice of a home range with adequate prey populations and potential breeding partners from within the landscape, then proceeding with the selection of a breeding territory within the home range, and finally with selection of a nest tree within the breeding territory (Johnson 1980, Kennedy 1988, Reynolds *et al.* 1992).

Scientific investigations of bird nesting habitat have commonly focused on the vegetation of the nest areas (Mosher *et al.* 1986, Mosher *et al.* 1987, Morrison *et al.* 1992). Nesting habitat studies may employ descriptions of the vegetation used by the birds in order to characterize the nest area (McGowan 1975, Shuster 1980, Hayward and Escano 1989), or may make inferences on the critical characteristics of nesting habitat that drive nest site selection by contrasting nest areas with points in the surrounding landscape (Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Squires and Ruggiero 1996). Within the second group of studies, the investigation may be conducted at a variety of spatial scales, including nest tree (contrasting the tree containing the nest with the surrounding habitat; Squires and Ruggiero 1996), nest site (contrasting an area of habitat surrounding the nest with the surrounding habitat; Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Kimmel 1995, Squires and Ruggiero 1996), nest stand (contrasting the stand containing the nest with surrounding stands; Squires and Ruggiero 1996), and landscape (contrasting landscape conditions around the nest with landscape conditions in the area surrounding; Kimmel 1995).

I investigated nesting habitat used by Northern Goshawks (*Accipiter gentilis*) in deciduous-dominated (*Populus*-dominated) mixedwood forest stands distributed across central Alberta by examining Northern Goshawk nest areas occupied during 1952-1997, and by intensive study of

Northern Goshawk nest areas occupied during 1993-1996. Vegetation was sampled to characterize the habitat used by Northern Goshawks at the scale of nest tree and nest stand, and vegetation at nest areas (0.55 ha around the nest) were compared to the surrounding forest stand to examine selection of nest areas within deciduous-dominated mixedwood forest stands.

2.2 STUDY AREA

This study was conducted in two regions in central Alberta (119°-111°W, 55°-53°N). The study was concentrated on the Foothills Model Forest around the town of Hinton (53°25'N, 117°35'W; the western study area), and around the city of Edmonton (54°N, 114°W; the eastern study area). Sampling was performed in five ecoregions: the Montane Ecoregion, the Sub-alpine Ecoregion, Upper Boreal Cordilleran Ecoregion, Lower Boreal Cordilleran Ecoregion, and the Boreal Mixedwood Ecoregion distributed west to east across the study area (Corns and Annas 1986, Beckingham and Archibald 1996). Elevations range from 1500 m above sea level (Upper Boreal Cordilleran) to less than 800 m above sea level (Boreal Mixedwood Ecoregion) (Corns and Annas 1986, Beckingham and Archibald 1996).

In the western study area, forest cover is dominated by lodgepole pine (*Pinus contorta*), with lesser amounts of trembling aspen (*Populus tremuloides*), white spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), black spruce (*Picea mariana*) and sub-alpine fir (*Abies lasiocarpa*) (Corns and Annas 1986, Beckingham and Archibald 1996). Access is provided by paved highways (highways 16, 40, 47, and 93), a system of primary and secondary forest access roads, and seismic cutlines. Forested areas are relatively contiguous, and the primary form of disturbance is logging.

In the eastern study area, forest cover is dominated by trembling aspen, balsam poplar, jack pine (*Pinus banksiana*), white birch (*Betula papyrifera*), white spruce, and balsam fir (*Abies balsamea*) (Corns and Annas 1986). Access is provided by a network of paved and unpaved highways, township roads and range roads. Forested areas range in size, but are often small and surrounded by a matrix of agricultural fields.

2.3 METHODS

2.3.1 Nest Location Efforts

Within the Foothills Model Forest, Northern Goshawk nests were located by six methods: aerial searches by rotary aircraft, silent searches on foot, broadcast surveys on foot, by visiting known stick nests to check occupancy, by using radio-telemetry on adult Northern Goshawks, and by collecting breeding evidence from within stick nests on Northern Goshawk territories.

On April 17, 1995, an aerial survey was conducted over an area of deciduous and deciduous-dominated forest (trembling aspen, balsam poplar) north of highway 16, east and west of the town of Hinton using the methods of McGowan (1975). The flight was conducted prior to deciduous leaf flush in order to increase the chances of observing stick nests (McGowan 1975). The day was clear with good visibility, and five observers were aboard the aircraft. The helicopter maintained an altitude of approximately 70 m above ground during the flight. The flight covered 67 km, with a distance of 250 m scanned for the presence of stick nests on either side of the aircraft, resulting in an area of 34 km^2 searched. At the conclusion of the survey flight, a survey was conducted over an area with known stick nests, in order to evaluate the effectiveness of the aerial survey technique.

Silent searches for Northern Goshawks, and surveys accompanied by broadcasts of Northern Goshawk alarm calls, were used in areas associated with Northern Goshawk sightings, and in areas of favourable Northern Goshawk nesting habitat (according to Schaffer *et al.* 1996). Silent searches were performed by teams of 1-4 surveyors walking parallel transects prior to deciduous leaf flush (Fuller and Mosher 1981, Fuller and Mosher 1987). The distance between adjacent transects (spaced 50 to 100 m apart) was adjusted according to the proportion of coniferous trees in the area, because of their influence on the observability of stick nests. Prior to surveys, personnel were trained in the appearance of stick nests, and the identification of calls and physical characteristics of the Northern Goshawk, Cooper's hawk (*Accipiter cooperii*), Sharp-shinned Hawk (*Accipiter striatus*), Red-tailed Hawk (*Buteo jamaicensis*), and the Northern Goshawk mimic (Gray Jay (*Perisoreus canadensis);* Fuller and Mosher 1987, Joy *et al.* 1994). Broadcast stations were spaced 300 metres apart on separate transects that were separated by 260 metres. Stations on adjacent transects were offset by 130 metres (Kennedy and Stahlecker 1993, Joy *et al.* 1994). Teams of two surveyors were used, with the observers walking parallel lines separated by 80 m through the survey areas.

Stick nest records on the Foothills Model Forest Wildlife Observation Card Database, and stick nest locations that had been documented by other wildlife project personnel were investigated in order to locate Northern Goshawk territories. Stick nests found on Northern Goshawk territories were investigated for the presence of Northern Goshawk feathers from nestlings, and nest decoration to indicate previous occupation. Radio-telemetry locations on Northern Goshawks radiotagged during the first field season were used to find nests during the second field season.

The area sampled during silent searches and broadcast surveys was quantified using measurements and forest cover type determinations from aerial photographs (1:15 000) with verification from field notes made during surveys and ground truthing. The area sampled was grouped according to the following cover types: lodgepole pine (>80% lodgepole pine overstory vegetation), white spruce (>80% white spruce overstory vegetation), black spruce (>80% black spruce overstory vegetation), coniferous-dominated mixedwood (overstory vegetation >50% lodgepole pine, white spruce, and black spruce, with a minimum 20% component of deciduous overstory vegetation), deciduous (*Populus*) (>80% deciduous overstory vegetation), and deciduous-dominated (*Populus*-dominated) mixedwood (overstory vegetation >50% trembling aspen and balsam poplar, with a minimum 20% component of coniferous overstory vegetation). The area sampled during aerial searches was not quantified, due to concerns over the effectiveness of the aerial survey technique (see section 2.4.1).

In other parts of central Alberta, including the eastern study area around the city of Edmonton, additional Northern Goshawk nests were found by raptor banders, fish and wildlife research personnel, and local land owners (E. Pletz, T. Roper, E.T. Jones, J. Moore, R. Cromie, A. de Groot, C. Spytz, D. Mushtuk, C. McCallum, B. Olsen, H. Wollis personal communications). These nests were sighted from roadways, were found during searches in woodlots prior to leaf flush, or were found opportunistically during the course of other forest-related work. In some cases, individuals contributing data to this study restricted their search efforts to areas that contained large deciduous (*Populus*) trees with cavities which are potential nest sites for Northern Saw-whet Owls (*Aegolius acadicus*), Boreal Owls (*Aegolius funereus*), and Barred Owls (*Strix varia*). Other individuals searched for nests in areas where there were a variety of sizes and species of trees. Searches were also conducted in the vicinity of previously active Northern Goshawk nests, and in areas where Northern Goshawk adults aggressively attacked

nest searchers (E. Pletz, T. Roper, E.T. Jones, J. Moore, R. Cromie, A. de Groot, personal communications).

2.3.2 Sampling of Vegetation at Nest Areas and Contrast Areas

A potential bias exists (Titus and Mosher 1981, Siders and Kennedy 1996) in the allocation of sampling effort for the location of Northern Goshawk nests, owing to the preponderance of effort in deciduous-dominated mixedwood stands in the eastern study area (62% of all nests located, 71% of nests that received intensive vegetation sampling). To account for this potential bias, the vegetation contrast area for each nest area was located in the same forest cover type as that where the nest was found (see below, this section; Squires and Ruggiero 1996).

At each Northern Goshawk nest tree that received intensive vegetation sampling, the species of nest tree was recorded. The height of the nest tree, and the height of the nest were measured using a clinometer. The diameter at breast height (DBH = diameter of tree outside bark at a height 1.42 m above ground level) of each Northern Goshawk nest tree was measured using a diameter tape. A description of the nest position in the tree was recorded, including the total number of branches (excluding the tree bole) supporting the nest structure. The presence/absence of a flight corridor adjacent to the Northern Goshawk nest (>2 m opening, >5 m in length) was recorded (Mosher *et al.* 1987).

The nest area around each Northern Goshawk nest was defined as 0.55 ha (a circular area with a radius of 42 m) around the nest tree. Vegetation was sampled at Northern Goshawk nest areas, and in contrast areas using groups of five nested plots (0.04 ha, circular plot 11.3 m in radius; Figure 2.1) according to the design in Timony (1993) (see Appendix 1 for a complete listing of variables recorded). The plots were centred on the nest tree (or designated tree for the contrast plots), and the surrounding plots were each positioned 30 m away from the nest tree in the cardinal directions. The size of this sampling area in each nest area (0.20 ha) is larger than that typically found in the literature (0.04 ha; see Titus and Mosher 1981, Mosher *et al.* 1987, Hayward and Escano 1989, Squires and Ruggiero 1996), and was chosen to better sample the habitat chosen by the large and mobile Northern Goshawks, following the guidance in Speiser and Bosakowski (1987). The slope and aspect of the Northern Goshawk nest site, and each contrast site were measured in the centre plot using a clinometer and compass, respectively. Within each plot, trees (≥5 cm DBH) were identified to species, and the DBH of each tree was measured with a diameter tape. The DBH was also measured for standing dead trees in two

height classes (>5 m in height; snags), and standing dead trees (5 m≥height≥1.42 m; stubs). Saplings (<5 cm DBH, and >1.42 m in height) and seedlings (<5 cm DBH, and ≤1.42 m in height) were identified to species, and counted. The top (to 5 cm diameter) and base diameter, and length of each piece of downed woody debris was measured. Within each plot, five overstory trees (dominant or codominant) that were judged to be representative of the overstory vegetation were selected, and their height was measured using a clinometer. At a position five metres from the plot centre, in each of the cardinal directions, a canopy closure measurement was made using a spherical densiometer. This canopy closure measurement was taken such that shrubs were excluded from the measurement, but saplings were included. In the next level of the hierarchy, a 0.004 ha plot (circular plot 3.56 m in radius) was located at the centre of each 0.04 ha plot. Within this second plot, an ocular estimate of shrub coverage (%) was recorded. In the final level of the hierarchy, four 1 m^2 plots were located at 5 metres from the plot centre, in each of the cardinal directions. Within these plots, an ocular estimate of herb coverage (%) was recorded.

For each Northern Goshawk nest area, a corresponding contrast vegetation sampling area (0.20 ha) was located in a random direction, at a random distance (90 to 1090 m from the Northern Goshawk nest tree). Within the contrast sampling plots, vegetation was sampled according to the same protocol as in the Northern Goshawk nest areas. Contrast sampling areas were restricted to those areas that exhibited the same forest composition as those at the nest area (deciduous-dominated mixedwood), and they also exhibited the following characteristics (by subjective estimate):

- areas containing trees with an average height >8 m,
- areas containing trees with an average diameter >15 cm,
- areas exhibiting overstory canopy closure >30%.

These minimum requirements were chosen to exclude randomly chosen areas that were deemed unsuitable for Northern Goshawk nesting according to the findings of Schaffer *et al.* (1996), following the guidance in Speiser and Bosakowski (1987).

Additional Northern Goshawk nests were visited to collect basic vegetation measurements: the height of the nest tree, the nest height, the nest tree DBH, the total number of branches supporting the nest structure (excluding the tree bole), and a general description of the nest placement. For nests that did not receive any vegetation sampling, the records of nest observers

were consulted to document the description of the nest tree species, an ocular estimation of the nest height, and the year the nest was occupied (active 1952-1997; E. Pletz, T. Roper, E.T. Jones, J. Moore, R. Cromie, A. de Groot, C. Spytz, D. Mushtuk, C. McCallum, B. Olsen, H. Wollis personal communications).

2.3.3 Statistical Analysis

The data from intensive sampling provided quantitative information on habitat conditions in Northern Goshawk nest areas and contrast areas. In addition to the variables measured, the data were used to calculate the following for subsequent analysis: average diameter of trees (cm); average height of overstory trees (m); live basal area of trees (m^2/ha); total basal area (m^2/ha) (stems >5 cm DBH); and volume of downed woody debris (m^3/ha; Mosher *et al.* 1987). For the purposes of comparison, the count data for seedlings and saplings were combined into one variable quantifying live trees (<5.0 cm DBH). To quantify the number of dead trees present on nest and contrast areas, count data for snags and stubs were combined. The count data for live trees and dead trees were grouped into the following diameter classes: 5.0 - 14.9 cm DBH; 15.0 - 24.9 cm DBH; 25.0 - 34.9 cm DBH; 35.0 - 45 cm DBH; >45 cm in diameter at breast height. All count data for trees were combined to create the variable total live trees (>5 cm DBH)/hectare. Count data for live trees and dead trees were combined to create the variable total stems (>5 cm DBH). The composition of the nest areas was examined by determining the relative dominance of each tree species in the overstory vegetation in the nest area (Mosher *et al.* 1987).

All known Northern Goshawk nesting records were examined to identify territories which contained multiple nests. The affinity of Northern Goshawks for a particular nest tree species was explored by examining the choice of nest tree species in central Alberta, and by analyzing changes in nest tree species choice on the territories which were occupied in consecutive years. An assumption was made that the nest tree species chosen in each year was independent of the nest chosen in the preceding year. Additional information on nest tree species preference was collected by analyzing the species chosen by nesting Northern Goshawks for nests located in an unbiased fashion. Using data gathered during intensive sampling, the height of Northern Goshawk nest trees was compared with the average height of dominant and codominant trees in the nest area using a Wilcoxon paired-samples test. The diameter of the Northern Goshawk nest trees was compared with the average diameter for trees in the nest area using a Wilcoxon paired-samples test.

Nest site aspects were tested for differences from a uniform distribution using Rayleigh's test (Batschelet 1981, Zar 1984, Kennedy 1988). Nest sites exhibiting flat slope conditions (slope <3°; n=5) were excluded from this analysis. Vegetation at Northern Goshawk nest areas were compared with those at the contrast areas using a Wilcoxon paired-samples test for eight different variables: average height of overstory (m), average diameter (cm), total canopy cover (%), volume of downed woody debris (m^3/ha), live basal area (m^2/ha), total basal area (m^2/ha), total herb coverage (%), and total shrub coverage (%; Zar 1984). The α-value for these Wilcoxon paired-samples tests was set at 0.05 and was then corrected to $\alpha/8$ (0.05/8)=0.00625 in order to account for the multiple univariate comparisons made with the vegetation dataset (Miller 1981, Thomas and Taylor 1990, Wiggers and Kritz 1991). A multivariate analysis was not used because of the limited sample size (Morrison 1984). Chi-square analysis was used to examine for differences in the relative proportion of live and dead trees in individual diameter classes at nest areas and contrast sites (Zar 1984). In order to have adequate counts of trees in each diameter class for analysis, the count data for live trees in the two largest diameter classes was combined to create one diameter class of trees (>35 cm DBH). Similarly, the count data for dead trees in the three largest diameter classes were combined to create one diameter class of trees (>25 cm DBH).

2.4 RESULTS

2.4.1 Nest Location Efforts

No stick nests were observed during the aerial survey flight; two Red-tailed Hawks were the only raptors observed during the flight. The area was primarily deciduous (*Populus*) forest. When the aerial survey method was tested in an area known to contain stick nests, no stick nests could be found. The habitats overflown in the aerial surveys have not been quantified and presented with the results from the other methods owing to concerns over the effectiveness of this survey technique.

In the first field season of the study, silent searches for Northern Goshawk nesting territories occurred between March 13, 1995 and May 24, 1995 (Table 2.1 and Appendix 2). A total of 252.4 ha of forest area was searched in 34 search hours. During these surveys, 2 stick nests were located (2 nests in the deciduous-dominated mixedwood cover type; 0.059 stick nests/hour), and 14 individuals of 7 different raptor species were observed. In the second field season of the

study, silent searches began on February 8, 1996 and were last performed on August 25, 1996 (Appendix 2). A total of 2421 ha of forest area was searched in 456 search hours. Sixteen stick nests were located (3 stick nests in the coniferous-dominated mixedwood cover type, 3 stick nests in the trembling aspen dominated cover type, 10 stick nest in the deciduous-dominated mixedwood cover type; 0.035 stick nests/hour), and 16 individuals of 6 different raptor species and one unidentified raptor were observed.

In the first field season of the study, broadcast surveys were conducted from 2-28 June, 1995 (Table 2.1 and Appendix 2). A total of 615 ha of forest area was surveyed in 27 search hours. No stick nests were located during these surveys, and one Northern Goshawk was the only raptor observed. In the second field season, owing to the limited success of broadcast surveys during first year, broadcast surveys were only used on June 14, 1996 (Table 2.1 and Appendix 2). A total of 71 ha of forest area was surveyed in 12 search hours. No stick nests or raptors were observed during these surveys.

In the first field season, 17 stick nests were checked for occupancy on the Foothills Model Forest, and two were occupied by Northern Goshawks (Appendix 3). In the second field season, 57 stick nests were checked for occupancy on the Foothills Model Forest, and two were occupied by Northern Goshawks (Appendix 3). Two additional Northern Goshawk nests were located in the second field season by radio-telemetry on an adult Northern Goshawk, and following the positive identification of feathers from a Northern Goshawk nestling in a stick nest, respectively.

Consultation with raptor banders, fish and wildlife research personnel, and local land owners led to the identification of 39 additional Northern Goshawk nests (active 1952-1997) in other parts of central Alberta, including the eastern study area.

2.4.2 Sampling of Vegetation at Nest Areas and Contrast Areas

Northern Goshawks typically nested in deciduous trees (N=45; 37 nests in trembling aspen, 5 in balsam poplar, 1 in white birch, 1 in lodgepole pine, 1 in white spruce; Appendix 4). The mean DBH of nest trees was 30.0 centimetres ± 1.32 SE (range 16.1-46.2 cm, n=25). The mean height of nest trees was 21.9 metres ± 0.63 SE (range 14.4-28.0 m, n=25). The mean nest height was 14.86 metres ± 0.46 SE (range 10.8-21.8 m). Nests were typically placed at the base of the canopy in a primary branch fork (19 of 25 nests), but were also situated within the crown of the nest tree (6 of 25 nests). Nests were positioned on whorls of branches (mean number of

supporting branches = 4.00 ± 0.24 SE; mean nest height as a percent of nest tree height = 68.35% ± 1.78 SE; Figure 2.2). A total of thirty-one different territories were identified; ten of these territories contained nests that were occupied by Northern Goshawks in consecutive years (territories reoccupied for 2 to 4 years; Appendix 4). All territories which were reused had repeated use of deciduous (trembling aspen, balsam poplar) trees. On the Foothills Model Forest, where nest location efforts were conducted in a range of forest cover types, no Northern Goshawk nests were found in coniferous or coniferous-dominated stands (Table 2.1). Five of the seven Northern Goshawk nests on the Foothills Model Forest were located in an unbiased fashion (as a result of radio-telemetry readings, and observations by forest workers). Twelve of the thirty-eight Northern Goshawk nests in other parts of central Alberta, including the eastern study area were located in an unbiased fashion (as a result of search effort in stands with a variety of sizes and species of trees).

2.4.3 Statistical Analysis

Vegetation was intensively sampled around Northern Goshawk nests located on the Foothills Model Forest (n=6; nests active 1994-1996) and in central Alberta (n=11; nests active 1993-1996), and at contrast areas (N=17). Comparison of the Northern Goshawk nest trees with trees from within the nest area (Table 2.2) revealed that Northern Goshawk nest trees were taller than the surrounding canopy (Wilcoxon paired-samples test, P=0.0086), and had a larger diameter than those trees found in the surrounding area (Wilcoxon paired-samples test, P=0.0004). The overstory vegetation in Northern Goshawk nest areas was dominated by deciduous trees (trembling aspen, balsam poplar, white birch; mean relative dominance of deciduous trees=0.78 ± 0.05 SE), with coniferous trees also occupying the overstory (white spruce, lodgepole pine, black spruce; mean relative dominance of coniferous trees=0.22 ± 0.05 SE). The average DBH of overstory trees on all Northern Goshawk nest areas was 19.68 centimetres ± 0.77 SE (range 15.1 - 25.5 centimetres). Nest areas typically had multiple canopy layers of overstory vegetation (mean=1.92 ± 0.08 SE). Nest areas had a high degree of canopy closure at the nest area (mean=77.4% ± 1.68 SE), with limited understory development (Figures 2.3 and 2.4). Canopy gaps created by fallen trees (18 of 25 nests), human-made trails (6 of 25 nests), and proximity to streams with low grass cover (1 of 25 nests) created a flight corridor adjacent to the nest trees. Nest sites were typically in a mid- to lower-slope position (16 of 17 nests), and four of these nests were located at the toe of a slope. Northern Goshawk nest sites faced all directions except west (247.5° - 292.5°) and southwest (202.5° - 247.5°) (Figure 2.5). The distribution of nest

site aspect did not differ from random ($0.50>P>0.20$). There was no significant difference ($\alpha=0.00625$) between Northern Goshawk nest sites and contrast sites for the eight vegetation variables tested (Table 2.3). There was no significant difference in the proportion of live and dead stems in different diameter classes (Table 2.4) present at nest sites and contrast sites (Pearson Chi-square=7.2049, $0.75>P>0.50$).

2.5 DISCUSSION

2.5.1 Nest Habitat Characterization

Northern Goshawk nests in this study were found almost exclusively in large deciduous (*Populus*) trees. This finding may have been influenced by the nest location effort which sampled deciduous-dominated mixedwood stands with greater effort in the eastern study area. On the Foothills Model Forest, where 45% of nest searches (1508.4 ha) occurred in coniferous or coniferous-dominated stands, surveys failed to locate any Northern Goshawk nests in coniferous trees. The distance between sampling transects was reduced in coniferous and coniferous-dominated stands in order to increase the likelihood that stick nests were observed, but it is unknown whether stick nests were still missed by observers. Five of the seven Northern Goshawk nests on the Foothills Model Forest were located by unbiased means (from radio-telemetry observations, observations made by forest workers), and of these nests, one was found in a coniferous tree. Twelve of the thirty-eight nests located in other parts of central Alberta were located by unbiased means (from searches that sampled a range of tree sizes and species), and no nest was found in a coniferous tree. Although they are based on small sample size, these findings suggest that coniferous trees are not typically used for Northern Goshawk nest placement in central Alberta contrary to the conclusions of Squires and Ruggiero (1996), who found 62% of Northern Goshawk nests in coniferous trees (lodgepole pine, sub-alpine fir), and 38% of nests in deciduous trees (trembling aspen) based on a sample size of 39 nests in southcentral Wyoming. The repeated use of large trembling aspen trees for nest placement on Northern Goshawk territories that were active in consecutive years further indicates the value of this tree species for Northern Goshawk nesting in central Alberta.

Across their range, Northern Goshawks choose a variety of species of trees for nesting (Beebe 1974, Apfelbaum and Seelbach 1983). The key factor influencing tree choice appears to be the security of the nest foundation. The placement of Northern Goshawk nests at the base of the canopy in a primary branch fork has been noted in many studies (McGowan 1975, Shuster 1980,

Reynolds *et al.* 1982, Moore and Henny 1983, Speiser and Bosakowski 1987, Hayward and Escano 1989, Reynolds 1989, Squires and Ruggiero 1996), and is not restricted to deciduous nest trees (Shuster 1980, Reynolds *et al.* 1982, Moore and Henny 1983, Hayward and Escano 1989, Reynolds 1989, Squires and Ruggiero 1996). The cause of primary branch forking at the base of the crown of trembling aspen trees is unknown (Stan Lux, Canadian Forest Service, personal communication). Squires and Ruggiero (1996) noted that the high degree of self-pruning in trembling aspen and lodgepole pine trees makes them good candidates for nest placement. A nest at the base of the canopy may be a benefit to Northern Goshawk reproductive success because the nest is more accessible to approaching adult Northern Goshawks for nest defense or feeding activities (Hennessy 1978, Reynolds *et al.* 1982, Hayward and Escano 1989, Moore and Henny 1983, Hall 1984, Speiser and Bosakowski 1987). This nest position also affords the Northern Goshawk the best view of the forest area surrounding the nest tree (Hall 1984, Janes 1985).

In this study, Northern Goshawks used large trees (as indicated by height and diameter) for nest placement in deciduous-dominated mixedwood forest stands. This finding is consistent with habitat selection investigations in southcentral Wyoming, where Northern Goshawks were found nesting in the largest trees in the nest-tree area (0.04 ha) and nest stand (Squires and Ruggiero 1996). In New Mexico, Northern Goshawk nest trees were characterized as being the taller ones on the nest site (Kennedy 1988). Likewise, in Oregon, Northern Goshawks were noted for their use of large trees (Reynolds *et al.* 1982). Large trees offer a secure podium for nest construction, and a well-developed canopy immediately over the nest provides insolation moderating temperature change around the nest (Moore and Henny 1983, Reynolds 1983, Kennedy 1988, Crocker-Bedford and Chaney 1988). Large trees are more likely to have dead branches below the crown (Reynolds *et al.* 1982). These branches may be important as perch sites for nest defense and foraging; they may also provide nesting material, or to act as plucking posts (Schnell 1958, Reynolds *et al.* 1982, Kennedy 1988). In a study of Northern Goshawk populations in Utah, Hennessy (1978) found that fledging rate increased with the average tree diameter for the nest stand and with the size of the nest tree.

The stands used by nesting Northern Goshawks in this study exhibit a variety of attributes (i.e. multiple canopy layers, canopy gaps, large standing and fallen dead trees, multiple ages of trees) that characterize the mature seral stage of deciduous-dominated mixedwood vegetation in this part of North America (Perala 1990, Mehl 1992, Moir 1992). Other studies conducted in North

America have also concluded that the older seral stages of vegetation are important for Northern Goshawk nesting (Reynolds *et al.* 1982, Moore and Henny 1983, Speiser and Bosakowski 1987, Kennedy 1988, Hayward and Escano 1989, Squires and Ruggiero 1996). Northern Goshawks have a fairly large body size and wing span, and are not suited to hunting in dense young forests (Reynolds 1989, Reynolds *et al.* 1992, Duncan and Kirk 1994). Northern Goshawks typically forage over a large home range area but the region immediately around the nest is important for hunting during the nestling and fledgling period (Crocker-Bedford and Chaney 1988). Older forests seem to represent the best compromise in foraging habitats, allowing maneuverability and attack by the Northern Goshawk, with concealment of its approach (Devereux and Mosher 1984, Speiser and Bosakowski 1987, Reynolds 1989, Widen 1989). In a summary of Northern Goshawk nest stand characteristics from across North America, Apfelbaum and Seelbach (1983) noted that Northern Goshawks preferred to nest in mixed woodlands, secondly in deciduous woodlands, and lastly in pure conifer forests. It has been suggested that coniferous trees are an important component of Northern Goshawk nest stands for protection of the nest from low temperatures at the start of the breeding season (Speiser and Bosakowski 1987), and high temperatures as the breeding season progresses (Moore and Henny 1983).

The dense canopy closure noted in this study (77.4% ± 1.68 SE) falls within the range of measures recorded in other studies of Northern Goshawk nesting habitat (59.8-94%) (Table 2.5 - adapted from Siders and Kennedy 1994). The dense canopy closure of the nest stands creates a mild and stable microclimate (Reynolds *et al.* 1982, Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988). It has been suggested that since Northern Goshawks have evolved in the forest environment, they might exhibit a preference for a cool microclimate and a lack of sunlight during the breeding season (Wattel 1973, as cited in Reynolds *et al.* 1982; Crocker-Bedford and Chaney 1988). The incidence of predation by open-country raptors (Great-horned Owl (*Bubo virginianus*), Red-tailed Hawk), and mammals (Fisher (*Martes pennanti*)) may be lower in closed canopy stands (Crocker-Bedford 1990, Reynolds *et al.* 1992, Erdman *et al.* 1998).

All Northern Goshawk nests visited during this study (n=25) had a canopy opening immediately adjacent to the nest tree. These openings may be important to act as Northern Goshawk flyways (Shuster 1980, Moore and Henny 1983, Hall 1984, Speiser and Bosakowski 1987). Northern Goshawk nests in close proximity to woodland trails have been noted in other studies, and this

nest location has been suggested to aid in orientation of the foraging Northern Goshawks to the nest (Speiser and Bosakowski 1987).

The choice of mid- to lower-slope positions has been noted in other Northern Goshawk nesting studies (McGowan 1975, Reynolds *et al.* 1982, Speiser and Bosakowski 1987, Hayward and Escano 1989, Squires and Ruggiero 1996), and this preference may be owing to the proximity to sources of water (Reynolds *et al.* 1982). The distance from Northern Goshawk nest sites to water was not measured in this study.

2.5.2 Nest Habitat Selection

Northern Goshawks in central Alberta did not exhibit a preference for nest site aspect. It has been suggested that this characteristic of nest site influences levels of protection, levels of soil moisture in nesting microenvironment, and overall stand structure (Reynolds *et al.* 1982, Crocker-Bedford and Chaney 1988, Crocker-Bedford 1994). In studies which concluded that Northern Goshawks exhibit a preference for nest site aspect, north facing sites are generally preferred in the more southern parts of the Northern Goshawk range (Colorado - Shuster 1980, Oregon - Reynolds *et al.* 1982, California - Hall 1984, Arizona - Crocker-Bedford and Chaney 1988, Idaho - Hayward and Escano 1989, Arizona - Ingraldi and MacVean 1994). This may be owing to the fact that northern aspects receive less solar radiation, and thus have greater soil moisture which results in greater leaf areas (Reynolds *et al.* 1982). Additional leaf area could contribute to the protection of Northern Goshawk nest sites and could result in cooler temperatures during the breeding season, and could result in reduced understory vegetation (Reynolds *et al.* 1982, Hall 1984). The preference for nest site aspect has been noted to change to southern aspects in the more northern parts of the Northern Goshawk range (Alaska - McGowan 1975), although the use of southern aspects may have been related to the distribution of white birch and trembling aspen trees in that part of the Northern Goshawk range.

We inferred habitat selection among Northern Goshawks within stands used for nesting by comparing nest sites with random contrast sites. The lack of difference between the nest areas and contrast areas with regard to distribution of live and dead stem diameters and the eight vegetation characteristics tested suggests that Northern Goshawks do not select particular microhabitats in the deciduous-dominated mixedwood stands in central Alberta. There are differences between the design of this study and investigations of habitat selection from other parts of the range of the Northern Goshawk, and this hampers direct comparisons of the study

findings. Other investigations of Northern Goshawk habitat selection (Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Ingraldi and MacVean 1994, Squires and Ruggiero 1996) have been based on nest location efforts that were conducted in a variety of forest cover types. All of these studies employ comparisons based on the random location of contrast areas in all forest cover types. None of the studies directly compares the Northern Goshawk nest site with other areas in the same stand.

2.6 CONCLUSIONS

Northern Goshawks nests were found in deciduous (*Populus*) trees in central Alberta. Nests were found at the base of the tree canopy, at a primary branch fork. Nest trees were large live trees (as indicated by height and diameter). Nest stands exhibited characteristics associated with the mature seral stage of deciduous-dominated forest. The coniferous component of nest stands may be important because of its influence on nest area microenvironment. Northern Goshawks did not exhibit a preference for a particular nest site aspect. There is no significant difference between Northern Goshawk nest areas and random contrast areas within the same forest cover type with regard to the diameter distribution of live and dead stems, and eight different vegetation parameters, suggesting that Northern Goshawks do not select for a particular microenvironment within the deciduous-dominated mixedwood stands.

Table 2.1 - Area searched (ha) and stick nests (# in brackets) on the Foothills Model Forest 1995 - 1996 by forest cover type.

Survey Technique	Lodgepole Pine	White Spruce	Black Spruce	Coniferous-dominated Mixedwood	Trembling Aspen	Deciduous-dominated Mixedwood
Silent Searches 1995	38.0(0)	5.0(0)		78.3(0)		129.1(2)
Broadcast Surveys 1995	136.8(0)	28.3(0)		129.5(0)	127.1(0)	193.1(0)
Silent Searches 1996	671.5(0)	170.8(0)	163.0(0)	73.1(3)	458.6(3)	884.2(10)
Broadcast Surveys 1996				14.1(0)	35.4(0)	21.2(0)
TOTAL	846.3	204.1	163.0	295.0	621.1	1227.6
% of TOTAL	25.2	6.1	4.9	8.8	18.5	36.6

Table 2.2 - Comparison of Northern Goshawk nest trees to nest stands in central Alberta.

Habitat Variables	Nest Sites (n=17)		Nest Stands (n=17)		Wilcoxon Matched-Pairs Test Statistic	*P*-value
	Mean	S.E.	Mean	S.E.		
Tree Height (m)	22.65	0.60	20.98*	0.52	-2.6273	0.0086
Tree DBH (cm)	30.35	1.34	19.68**	0.77	-3.5740	0.0004

* - average of 25 trees/nest area.

** - average of all stems >5 cm DBH in the nest area.

Table 2.3 - Comparison of Northern Goshawk nest sites and contrast sites in central Alberta.

Nest Site Variable	Nest Site (n=17)		Contrast Sites (n=17)		*P*-value- Wilcoxon Matched Pairs Test
	Mean	S.E.	Mean	S.E.	
Average Height of Overstory (m)	21.0	0.52	21.2	0.49	0.5699
Average DBH (cm)	19.7	0.77	19.7	0.75	0.8684
Total Canopy Closure (%)	77.4	1.68	72.9	1.79	0.0312
Volume of Downed Woody Debris (m^3)	4.9	0.62	5.3	0.75	0.4925
Live Basal Area (m^2/ha)	5.6	0.26	5.3	0.42	0.4631
Total Herb Coverage (%)	36.0	2.47	34.7	2.18	0.9058
Total Shrub Coverage (%)	45.4	4.06	44.8	3.49	0.9058
Total Basal Area (m^2/ha)	6.4	0.26	6.3	0.39	0.6874

Table 2.4 - Frequency of live and dead stems by DBH class (cm) at Northern Goshawk nest areas and contrast areas.

Sampling Area	All Trees	Live Trees by DBH class (cm)					All Live Trees	Dead Trees by DBH Class (cm)			All Dead Trees
		<5.0	5.0-14.9	15.0-24.9	25.0-34.9	>35.0		5.0-14.9	15.0-24.9	>25.0	
Nest Area	1980	285	314	164	34	797	1041	162	68	12	243
Contrast Area	1784	275	303	146	42	763	1041	181	78	18	277

Table 2.5 - Average canopy closure for Northern Goshawk nest stands (%).

Location	Canopy Closure (%)	Sample Size	Method of Measurement	Source
Alberta, central	77.4	17	Spherical densiometer	this study
Arizona	76.0	36	Spherical densiometer	Crocker-Bedford and Chaney (1988)
California, N.W.	94.0	10	Spherical densiometer	Hall (1984)
Montana - Idaho	80.0	17	Spherical densiometer	Hayward and Escano (1989)
New Mexico	65.7	42	Spherical densiometer	Siders and Kennedy (unpubl. data)
New York - New Jersey	90.0	16	Ocular sighting tube	Bosakowski *et al.* (1992)
Oregon, E.	59.8	7	Ocular estimate	Reynolds *et al.* (1982)
Wyoming	66.7	39	Line-intercept sampling	Squires and Ruggiero (1996)

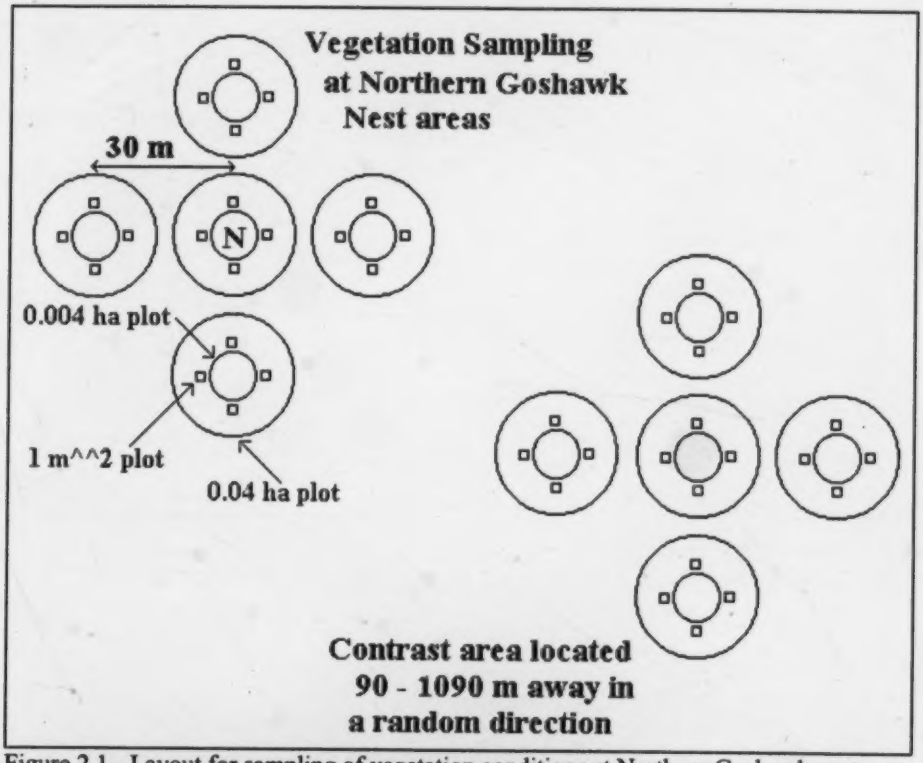

Figure 2.1 - Layout for sampling of vegetation conditions at Northern Goshawk nest areas and contrast areas in central Alberta.

Figure 2.2 - Adult Northern Goshawk on a nest in a trembling aspen tree (photo by W. Schaffer).

Figure 2.3 - Northern Goshawk nest area in a deciduous-dominated stand (photo by W. Schaffer).

Figure 2.4 - Northern Goshawk nest area in a coniferous-dominated stand (photo by W. Schaffer).

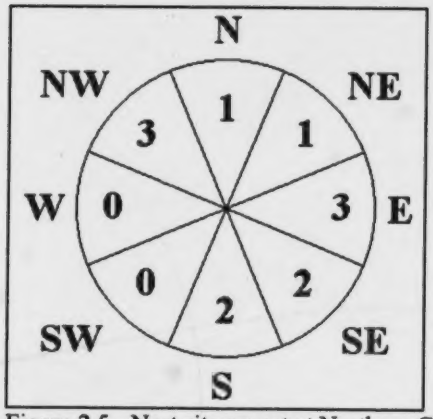

Figure 2.5 - Nest site aspect at Northern Goshawk nests in central Alberta (n=12).

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3.0 Northern Goshawk (*Accipiter gentilis*) diet during the breeding season in central Alberta

3.1 INTRODUCTION

Breeding density of raptors depends largely on habitat structure and composition, and food availability in the form of suitably sized prey (Storer 1966, Hespenheide 1975, Newton 1976, Newton 1979, Kenward 1982, Janes 1985, Klopfer and Ganzhorn 1985, Widen 1989, Reynolds *et al.* 1994, Crocker-Bedford 1994, Dunk and Cooper 1994, Solonen 1997). Presence of prey species of suitable size does not equate with prey availability (Southern and Lowe 1968, Johnson 1980, Baker and Brooks 1981, Bechard 1982, Kenward 1982, Widen 1989, Preston 1990, Widen 1994, Beier and Drennan 1997). Prey availability is influenced by the hunting ability and morphology of the predator (Marti 1974, Solonen 1997), the structure of the foraging environment (Bechard 1982, Janes 1985, Widen 1989, Preston 1990, Widen 1994), the physical appearance, size, escape ability and behaviour of individual species of prey (Hespenheide 1975, Cresswell 1995, Tornberg 1997), and the size of the population of cyclic prey species (Snowshoe Hare (*Lepus americanus*), Ruffed Grouse (*Bonasa umbellus*); Keith *et al.* 1977, Doyle and Smith 1994, Erdman *et al.* 1998).

Northern Goshawks (*Accipiter gentilis*) require 120-150 g of food per day or about 10-15% of their body weight (Brown and Amadon 1968). In North America, the average Northern Goshawk clutch size is 2.7 ± 0.88 SD chicks (n=44; Apfelbaum and Seelbach 1983). From birth to fledging, two nestling Northern Goshawks require about 13 kg of food (Brown and Amadon 1968). Depending on the size of prey taken, Northern Goshawk adults have to capture between 100-250 prey items to achieve this mass (Jones 1979). Ward and Kennedy (1996) suggested that breeding success of Northern Goshawks is food limited. The migratory behaviour of Northern Goshawks in response to cycles in the populations of major prey species (Keith *et al.* 1977, Mueller *et al.* 1977) provides strong circumstantial evidence of the link between Northern Goshawk breeding density and food supply (Newton 1976, Doyle and Smith 1994).

A variety of sampling techniques have been developed for the study of raptor prey use, including direct methods: nest observation and photographic recording; and indirect methods: pellet analysis, prey remain identification, and isotope analysis (Errington 1932, Sherrod 1978, Johnson 1981, Marti 1987, Duxbury 1998). Indirect methods of diet determination may be

biased and the analysis of prey use data from studies employing indirect methods should reflect this bias (Marti 1987, Simmons *et al.* 1991, Bielefeldt *et al.* 1992).

The diet and habitat use of Northern Goshawks has been investigated in various locales (see reviews by Jones 1979, Reynolds *et al.* 1992, and Squires and Reynolds 1997). Reynolds and Meslow (1984) combined information on prey use with descriptions of the life history of prey species to examine partitioning of microhabitat resources, and differences in foraging strategies within the genus *Accipiter*. Few studies have examined Northern Goshawk foraging habitat, and foraging habitat-use preferences are poorly understood in North America (Bright-Smith and Mannan 1994, Squires and Reynolds 1997).

I investigated prey use by Northern Goshawks during the breeding season (nests active 1993-1996) in deciduous-dominated (*Populus*-dominated) mixedwood forest stands distributed across central Alberta. Data were collected from nests in west-central Alberta (around the town of Hinton), and in east-central Alberta (around the city of Edmonton). The data from the direct sampling technique (nest observation - employed in the western study area) was used to characterize Northern Goshawk diet. Data from an annual survey of trappers in the province of Alberta was used to provide information on the status of Snowshoe Hare populations during the study years. In a development of the approach taken by Reynolds and Meslow (1984), I used information on the microhabitat associations of Northern Goshawk prey species, combined with knowledge of Northern Goshawk hunting tactics in order to draw inferences on the characteristics of Northern Goshawk foraging environments. Owing to the differences in the distribution of prey species across the province (Flack 1976, Erskine 1977), the prey use data gathered by indirect sampling techniques was divided according to study area. Northern Goshawk diet as determined by indirect sampling was compared in the western and eastern study areas by testing for differences in the relative contribution of key prey species.

3.2 STUDY AREA

A detailed study area description is found in section 2.2.

3.3 METHODS

3.3.1 Prey Use

Northern Goshawk diet in the western study area was characterized by: direct observation of feeding behaviour at active Northern Goshawk nests (two nests in 1995, three nests in 1996; following the techniques presented in Schnell 1958, Marti 1987), collection of pellets and prey remains (two nests in 1995, three nests in 1996; following the techniques presented in Errington 1932, Joy *et al.* 1994), and by consulting raptor banders to document any prey items recorded at the time of banding of Northern Goshawk chicks (one nest in 1994; following techniques presented in Marti 1987). Observation blinds were constructed on the ground (2 nests), mounted on observation towers (2 nests) or mounted on a tree in the nest stand (1 nest) at a mean distance of 25 m from the nest trees. The daylight period of observation days was divided into two equal periods, and the observation period was alternated between these periods. Weekly collections of pellets and prey remains were conducted around active Northern Goshawk nests and around alternate nests on active territories. The area surrounding Northern Goshawk nests was investigated for plucking posts. Following the breeding season, additional pellet and prey remain collections were made from the nests. Information on Northern Goshawk diet in the eastern study area were obtained by: collection of pellets and prey remains from the vicinity of nests following the breeding season (seven nests in 1996), and by consulting raptor banders to document any prey items recorded at the time of banding of Northern Goshawk chicks (three nests in 1996).

During nest observation periods, the identity, size and condition (i.e. whole, plucked, pelage absent) of individual prey items were recorded (Johnson 1981, Reynolds and Meslow 1984). Northern Goshawk pellets were dissected and examined macroscopically (Marti 1987). The number of prey items present in pellets and prey remain collections was estimated using the maximum number of body parts present (i.e. femurs, feet, mandibles, skulls, feathers; Collopy 1983, Marti 1987, Joy *et al.* 1994). Specimens were compared to the reference collection at the Museum of Zoology, University of Alberta. Immature prey items were identified by pronounced differences in scull sizes, and epitrichium sheathing on flight or tail feathers (Joy *et al.* 1994).

Prey biomass in the diet is useful for assessing the relative importance of prey species (Johnson 1981, Marti 1987). Biomass was assigned to prey items using the mean weight for adults of the species using estimates from published sources (Steenhoff 1983, Dunning 1984, Smith 1993) and local data (M. Wheatley, University of Alberta, unpublished data). Immature prey were assigned

a weight that was one-half the adult weight (Reynolds *et al.* 1994). Prey items that were identified only to genus were assigned the average body mass for individuals of that genus that were recorded as prey in this study. Unidentified prey items were assigned the average body mass of prey from that taxa as recorded by this study (Joy *et al.* 1994).

3.3.2 Prey Population Status - Questionnaire of Registered Trappers

Information on the status of Snowshoe Hare populations was compiled from the data gathered by a questionnaire circulated annually (1988-1995) to registered trappers in the province of Alberta (A.E.P. 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995). The questionnaire was designed to gather subjective information on the status of furbearers and game animals based on observations made during trapping. A status index for each survey year was computed by subtracting the percentage of respondents that indicated that Snowshoe Hares were scarce from the percentage of respondents that indicated that Snowshoe Hares were abundant (A.E.P. 1994). The number of respondents in the Eastern Slopes survey area (which contains the western study area) varied from a minimum of 202 respondents (1995) to a maximum of 300 respondents (1988). The total number of respondents in the province of Alberta varied from a minimum of 795 respondents (1995) to a maximum of 1455 respondents (1989).

3.3.3 Diet Characterization and Prey Description - Direct Sampling Technique

Prey use data gathered by direct sampling techniques (nest observation - employed on the western study area) was used to characterize Northern Goshawk diet. Prey were categorized based on the size classes of body mass in Storer (1966). These categories were designed for *Accipiter* diet studies, and they arrange prey species of similar form in categories differing by a constant increase in linear measurements (Storer 1966). Prey species were described based on their foraging position in four height zones (ground-shrub, shrub-canopy, canopy, aerial) following the design presented in Reynolds and Meslow (1984) based on published accounts of life histories (Banfield 1974, Kaufman 1996). It was assumed that the prey occupied this position in the forest when detected by the Northern Goshawk. Prey species that could not be assigned to one zone were classified as a generalist (Reynolds and Meslow 1984). Information on the foraging position of Northern Goshawk prey from the direct sampling techniques was combined with information on the foraging behaviour of Northern Goshawks to construct a description of the Northern Goshawk foraging environment in the western study area.

3.3.4 Diet Comparison - Western *versus* Eastern Study Area

An assumption was made that although indirect sampling techniques are biased, this bias is reflected equally in both the western and eastern study areas. Information obtained from indirect methods was used to draw conclusions on the breadth of Northern Goshawk diet across the province of Alberta. The proportion of diet contributed by Snowshoe Hares, Red Squirrels (*Tamiasciurus hudsonicus*), and Ruffed Grouse, as detected by indirect sampling in the two study areas was compared using a Chi-Square analysis.

3.3.5 Additional Diet Information

Additional Northern Goshawk prey were obtained from mortality of radio-tagged Pileated Woodpeckers (*Dryocopus pileatus*) on the Foothills Model Forest (kill sites located 1993-1995; R. Bonar, Biologist, Weldwood of Canada, personal communication), by using radio-telemetry to walk in on radio-tagged Northern Goshawks and locate their kill sites on the snow (Widen 1989), from observations made at Northern Goshawk nests at the time of banding according to records of raptor banders (nests occupied in 1971, 1988, 1990, 1992, and 1993), and from sightings of Northern Goshawk foraging behaviour or kill sites in central Alberta (observations made during 1946, 1951, 1953, 1955, 1956, 1971; E. Pletz, A. de Groot, T. Roper, E.T. Jones, R. Cromie, J. Moore, personal communications; W. Schaffer, unpublished data). This diet information was sporadic (with many single records of prey use per breeding territory), and was collected from disparate sources to present supplementary information on the breadth of Northern Goshawk diet in central Alberta but it was not used as a basis for conclusions on diet composition.

3.4 RESULTS

3.4.1 Diet Characterization and Prey Description - Direct Sampling Technique

A total of 33 prey items were identified from 170 hours of nest observation (Table 3.1). The mean weight of Northern Goshawk prey was 299.66 grams (Table 3.1 and Appendix 5). The majority of the Northern Goshawk diet was composed of prey species from the larger size classes (Figure 3.1). Snowshoe Hare, and Red Squirrel were the dominant prey species. The mean weight of mammalian prey was 408.94 g (range 26.80 - 1435.00 g), and mammalian prey composed 88.6% of Northern Goshawk diet (by biomass). The mean weight of avian prey was 190.38 g (range 31.00 - 576.50 g), and avian prey composed 11.4% of Northern Goshawk diet

(by biomass). During daylight hours, Northern Goshawk prey were typically found in the ground-shrub layer of vegetation (67.84% of prey; Table 3.2).

3.4.2 Status of Snowshoe Hares - Results from Survey of Trappers

Questionnaire results from the Eastern Slopes survey area and the province of Alberta show similar trends for changes in the status index for Snowshoe Hares. The status index exhibits a gradual increase through the years 1988-1990, and a sharp decrease in the years 1991-1993, with a slight increase in the years 1994-1995 (Figure 3.2).

3.4.3 Diet Comparison - Indirect Sampling Techniques

In the western study area, a total of 49 prey items were identified from 66 pellets and 34 prey remain collections (Table 3.3). Snowshoe Hare (41.49%), Ruffed Grouse (21.43%), Red Squirrel (13.43%), Spruce Grouse (*Falcipennis canadensis*; 5.87%), and Blue Grouse (*Dendragapus obscurus*; 4.29%) comprised the majority of Northern Goshawk diet (by biomass; Appendix 5). In the eastern study area, a total of 49 prey items were identified from 74 pellets and 16 prey remain collections (Table 3.4). Snowshoe Hare (28.47%), Mallard (*Anas platyrhynchos*; 18.69%), Ruffed Grouse (18.30%), Richardson's Ground Squirrel (*Spermophilus richardsonii*; 10.98%), and Red Squirrel (4.30%) comprised the majority of Northern Goshawk diet (by biomass; Appendix 6). There was no difference in the relative proportion of Snowshoe Hare, Ruffed Grouse, and Red Squirrel in Northern Goshawk diet in the two study areas (Pearson Chi-square = 2.0968, $0.75<P<0.50$).

The indirect sampling found that certain prey formed a portion of Northern Goshawk diet in only one study area:

- prey unique to Northern Goshawk diet in the western study area were Pika (*Ochotona princeps*), Blue Grouse, Spruce Grouse, Pileated Woodpecker, Northern Flicker (*Colaptes auratus*), Three-toed Woodpecker (*Picoides tridactylus*), Gray Jay (*Perisoreus canadensis*), Black-throated Green Warbler (*Dendroica virens*);
- prey unique to Northern Goshawk diet in the eastern study area were Richardson's Ground Squirrel, Green-winged teal (*Anas crecca*), Blue-winged Teal (*Anas discors*), Mallard, Northern Shoveler (*Anas clypeata*), Sharp-shinned Hawk, Yellow-bellied Sapsucker (*Sphyrapicus varius*), Blue Jay (*Cyanocitta cristata*), Black-billed Magpie (*Pica pica*).

3.4.4 Additional Prey Information

The prey use information gathered from kill sites and sightings revealed that Muskrat (*Ondrata zibethica*), Hungarian Partridge (*Perdix perdix*), Great Gray Owl (*Strix nebulosa*), Northern Saw-whet Owl (*Aegolius acadicus*), American Crow (*Corvus brachyrynchos*), Varied Thrush (*Ixoreus naevius*), European Starling (*Sturnus vulgaris*), domestic chicken (*Gallus gallus*), and domestic turkey (*Meleagris gallopavo*) also compose a portion of the diet of Northern Goshawks in central Alberta (Appendix 7).

3.5 DISCUSSION

3.5.1 Comparison of Diet Determination Methods

None of the methods for diet study are effective for recording prey items consumed by adult birds away from the nest site (Sonerud 1989, Jacobsen and Sonerud 1993, Tornberg 1997). Indirect sampling techniques may be biased towards the detection of large or avian prey (Errington 1932, Marti 1987, Simmons *et al.* 1991, Bielefeldt *et al.* 1992, Oro and Tella 1995). In this study, different methods were used in the western and eastern study areas (direct and indirect sampling *versus* indirect sampling), and the prey data were divided by study area and by the sampling technique employed. Owing to low sample size, comparisons amongst the diet determination techniques were not possible (Zar 1984).

3.5.2 Diet Composition - by Size

The high proportion of medium- to large-sized prey in Northern Goshawk diet is also consistent with other studies (Henderson 1924, Meng 1959, Storer 1966, Root and De Simone 1978, Jones 1979, Palmer 1988, Widen 1989, Bosakowski and Smith 1992b, Bull and Hohmann 1994, Doyle and Smith 1994). The larger-sized prey represent a more efficient energy expenditure by foraging Northern Goshawks owing to their large body size (Storer 1966, Reynolds and Meslow 1984, Stephens and Krebs 1986).

3.5.3 Diet Composition - by Taxa

Northern Goshawks are regarded as an opportunistic predator, although they may also focus on a few prey species at a given time or place (Storer 1966, Palmer 1988). In contrast to some other raptors, the agility of Northern Goshawks allows them to hunt both mammalian and avian prey (Bosakowski and Smith 1992a; see Appendix 8 for diet composition from other studies). The wide spectrum and varied size of prey in the diet of Northern Goshawks in both the western and

eastern study areas are consistent with other studies (Schnell 1958, Root and DeSimone 1978, Reynolds and Meslow 1984, Palmer 1988, Bosakowski and Smith 1992b, Boal and Mannan 1994, Reynolds *et al.* 1994). The diet breadth could arise due to the sexual size dimorphism exhibited by Northern Goshawks (Storer 1966, Snyder and Wiley 1976), changes in Northern Goshawk prey choice to partially deal with cyclical or low density of prey populations (Schoener 1969, Newton 1976, Hamerstrom 1979, Linden and Wikman 1983, Boal and Mannan 1994) or may be a reflection of the changes in prey availability over the course of the breeding season due to timing of hibernation, fledging, inactivity, and migration in prey species (Schnell 1958, Snyder and Wiley 1976, Steenhof and Kochert 1988, Reynolds *et al.* 1992, Jacobsen and Sonerud 1993, Younk and Bechard 1994, Tornberg 1997). Northern Goshawk predation can depress certain prey populations (Eng and Gullion 1962), but the use of a wide variety of prey species has the effect of spreading out the impact of predation (Snyder and Wiley 1976).

There was no difference in the relative contribution of key prey species (Snowshoe Hare, Red Squirrel and Ruffed Grouse) between the two study areas. Heavy use of these species in central Alberta could represent selection of prey species that are present year-round (Storer 1966, Widen 1984). Information from the questionnaire completed by trappers in the province of Alberta indicates that Snowshoe Hares reached a peak abundance in 1990, and were moderately abundant during the study years. These findings are agreement with observations on the status of Snowshoe Hares in the Yukon (Mowat *et al.* 1996), and Wisconsin (Erdman *et al.* 1998), and are consistent with the 10-year cycle observed to operate in these populations (Keith 1963). Scientific investigations have found a high degree of synchrony between the cycle of Snowshoe Hares and Ruffed Grouse (Keith *et al.* 1977, Mueller *et al.* 1977). There may be a shift in the diet of Northern Goshawks towards alternative prey during years of lower abundance of Snowshoe Hares and Ruffed Grouse (Doyle and Smith 1994).

3.5.4 Northern Goshawk Hunting

The predominant hunting technique used by Northern Goshawks involves scanning for prey and initiating attack from frequently changed perches (the short-sit-and-wait-short-flight technique) (Kenward 1982, Widen 1984, Fischer 1986). Surprise attack is sudden and swift, although reckless pursuit of the quarry may occur (Duncan and Kirk 1994, Squires and Reynolds 1997). Other hunting is undertaken on the wing with prey already in flight (Kenward 1982, Widen 1985), by flushing prey (Widen 1984, Johnsgard 1990), or by pursuing prey on foot (Schnell 1958, Brown and Amadon 1968, Jones 1979, Bergstrom 1985). Northern Goshawk hunting

success relies on the structure of the hunting microenvironment for concealment of the perched predator, open attack flight corridor, and visibility of the prey (Reynolds and Meslow 1984, Janes 1985, Widen 1989, Widen 1994, Beier and Drennan 1997). Habitats with few perch sites due to low densities of vegetation, or where open vegetation conditions do not provide adequate concealment of the predator are less desirable foraging habitats for Northern Goshawks (Austin 1993).

3.5.5 Northern Goshawk Foraging Environments in west-central Alberta

During the Northern Goshawk breeding season in central Alberta, Snowshoe Hares are found in forested areas with dense understory cover and herbaceous forage, that are interspersed with areas of good cover, in the form of coniferous vegetation (Meslow and Keith 1968, Keith 1974). Red Squirrels require mature coniferous forest for optimum cover and food supplies (Kemp and Keith 1970, Rusch and Reeder 1978). Ruffed Grouse populations are dependent on mature aspen forest, with well developed shrub layers, and drumming logs (Boag and Sumanik 1969, Rusch and Keith 1971).

The large body size of the Northern Goshawk precludes the use of denser forest for foraging even though populations of key prey may be greater in those habitats (Fischer 1986, Widen 1989, Bosakowski and Smith 1992a, Reynolds *et al.* 1992, Duncan and Kirk 1994). The high use of medium- and large-sized prey from the lower strata of the forest in the western study area corresponds to other studies where Northern Goshawks were using mature forests with relatively open understories for hunting (Moore and Henny 1983, Reynolds and Meslow 1984, Speiser and Bosakowski 1987, Hayward and Escano 1989, Widen 1989, Hargis *et al.* 1994, Beier and Drennan 1997). Ground-dwelling mammalian and ground-foraging avian prey are easier to capture than other avian prey because of a lower number of escape routes on the forest floor (Storer 1966, Hespenheide 1975, Reynolds and Meslow 1984, Bielefeldt *et al.* 1992, Selas 1993). Habitat variation and the juxtaposition of younger forested areas with mature forest may benefit Northern Goshawk foraging by having areas of high prey abundance situated near good foraging habitat (Southern and Lowe 1968, Reynolds *et al.* 1992, Hargis *et al.* 1994).

3.6 CONCLUSIONS

Northern Goshawks use a wide range of prey in central Alberta, but concentrate on medium- to large-sized mammals and birds. In west-central Alberta, Northern Goshawks use mature and old forest age classes for foraging due to availability of key prey species in those habitats. An

interspersion of habitat age classes could provide areas where prey populations will thrive (younger age classes of forest), adjacent to areas where prey are available to the Northern Goshawks (older age classes of forest).

Table 3.1 - Diet of Northern Goshawks on the western study area as detected by the direct sampling technique.

Prey Species	Frequency of Prey Species	Diet Composition		
	Direct Observation	Percent of Total Biomass	Prey Size Class[a]	Foraging Zone[b]
MAMMALS	**25**	**88.6**		
Snowshoe Hare (*Lepus americanus*)	6	63.97	20	1
Red Squirrel (*Tamiasciurus hudsonicus*)	13	20.94	10	5
Bushy-tailed Woodrat (*Neotoma cinerea*)	1	2.49	11	1
Meadow Vole (*Microtus pennsylvanicus*)	3	0.69	4	1
Unidentified Microtine	2	0.46	3	1
BIRDS	**8**	**11.4**		
Ruffed Grouse (*Bonasa umbellus*)	1	4.28	14	5
Pileated Woodpecker (*Dryocopus pileatus*)	2	4.26	11	3
Northern Flicker (*Colaptes auratus*)	2	1.65	7	5
Three-toed Woodpecker (*Picoides tridactylus*)	1	0.49	6	3
Gray Jay (*Perisoreus canadensis*)	1	0.53	6	5
Hermit Thrush (*Catharus guttatus*)	1	0.23	4	1
TOTAL PREY	**33**	**100**		

[a] - from Storer (1966): (1) 3.4-8g; (2) 8-15.6g; (3) 15.6-27g; (4) 27-42.9g; (5) 42.9-64g; (6) 64-91.1g; (7) 91.1-125g, (8) 125-166g; (9) 166-216g; (10) 216-275g; (11) 275-343g; (12) 343-422g; (13) 422-512g; (14) 512-614g; (15) 614-729g; (16) 729-856g; (17) 856-1000g; (18) 1000-1158g; (19) 1158-1331g; (20) 1331-1521g.

[b] - from Reynolds and Meslow (1984): (1) ground-shrub; (2) shrub-canopy; (3) canopy; (4) aerial; (5) generalist, based on information found in Banfield (1974), Kaufman (1996).

Table 3.2 - Diet of Northern Goshawks on the western study area, as detected by the direct sampling technique, according to their foraging zone.

Vegetation Zone[a]	Biomass of Prey (%)
(1) Ground-Shrub	67.84
(2) Shrub-Canopy	
(3) Canopy	4.75
(4) Aerial	
(5) Generalist	27.41
TOTAL	**100.00**

[a] - from Reynolds and Meslow (1984), based on information found in Banfield (1974), Kaufman (1996).

Table 3.3 - Diet of Northern Goshawks on the western study area as detected by the indirect sampling techniques.

Prey Species	Frequency of Prey Species				Diet Composition
	Pellets	Prey Remains	Other Sightings	Total	Percent of Total Biomass
MAMMALS	**14**	**7**	**5**	**26**	**61.5**
Snowshoe Hare *(Lepus americanus)*		5	2	7	41.49
Snowshoe Hare (immature) *(Lepus americanus)*		2		2	5.93
Pika *(Ochotona princeps)*	1			1	0.57
Red Squirrel *(Tamiasciurus hudsonicus)*	12		3	15	13.43
Unidentified Microtine	1			1	
BIRDS	**11**	**10**	**2**	**23**	**56.25**
Blue Grouse *(Dendragapus obscurus)*		1		1	4.29
Spruce Grouse *(Falcipennis canadensis)*	3			3	5.87
Ruffed Grouse *(Bonasa umbellus)*		8	1	9	21.43
Pileated Woodpecker *(Dryocopus pileatus)*			1	1	1.19
Northern Flicker *(Colaptes auratus)*	1			1	0.46
American Robin *(Turdus migratorius)*		1		1	0.32
Hermit Thrush (Catharus guttatus)	1			1	0.13
Black-throated Green Warbler (Dendroica virens)	1			1	0.04
Unidentifed Passerine	1			1	0.19
Unidentified bird	4			4	4.53
TOTAL PREY	**25**	**17**	**7**	**49**	**100.00**

Table 3.4 - Diet of Northern Goshawks on the eastern study area as detected by the indirect sampling techniques.

Prey Species	Frequency of Prey Species				Diet Composition
	Pellets	Prey Remains	Other Sightings	Total	Percent of Total Biomass
MAMMALS	**3**	**10**	**5**	**18**	**43.75**
Snowshoe Hare (*Lepus americanus*)	1	4		5	28.47
Richardson's Ground Squirrel (*Spermophilus richardsonii*)		3	5	8	10.98
Red Squirrel (*Tamiasciurus hudsonicus*)	2	3		5	4.30
BIRDS	**0**	**30**	**1**	**31**	**56.25**
Green-winged Teal (*Anas crecca*)		2		2	2.71
Green-winged Teal (immature) (*Anas crecca*)		1		1	0.68
Blue-winged Teal (*Anas discors*)		1		1	1.53
Mallard (*Anas platyrhynchos*)		4		4	18.69
Mallard (immature) (*Anas platyrhynchos*)		1		1	2.34
Northern Shoveler (immature) (*Anas clypeata*)		1		1	2.43
Sharp-shinned Hawk (*Accipiter striatus*)		1		1	0.55
Ruffed Grouse (*Bonasa umbellus*)		8		8	18.30
Yellow-bellied Sapsucker (*Sphyrapicus varius*)		1		1	0.20
Blue Jay (immature) (*Cyanocitta cristata*)		1		1	0.17
Black-billed Magpie (immature) (*Pica pica*)		4		4	1.41
American Robin (*Turdus migratorius*)		1		1	0.31
Unidentified Duck		1		1	2.52
Unidentified Duck (immature)			1	1	1.51
Catharus spp.		1		1	0.12
Unidentified bird		2		2	2.80
TOTAL PREY	**3**	**40**	**6**	**49**	**100.00**

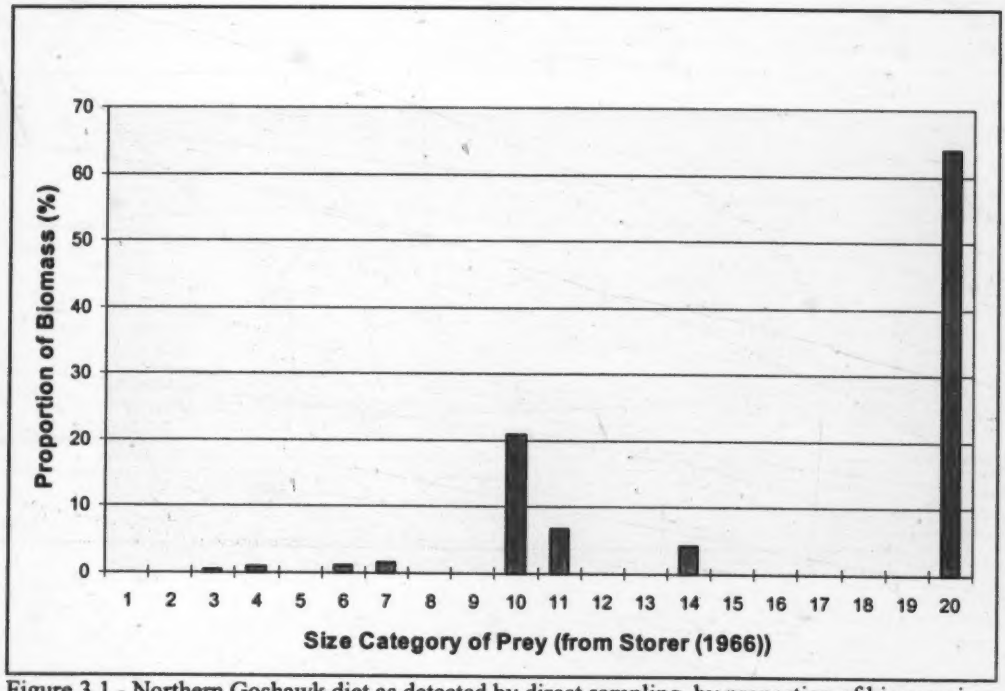

Figure 3.1 - Northern Goshawk diet as detected by direct sampling, by proportion of biomass in size classes presented in Storer (1966).

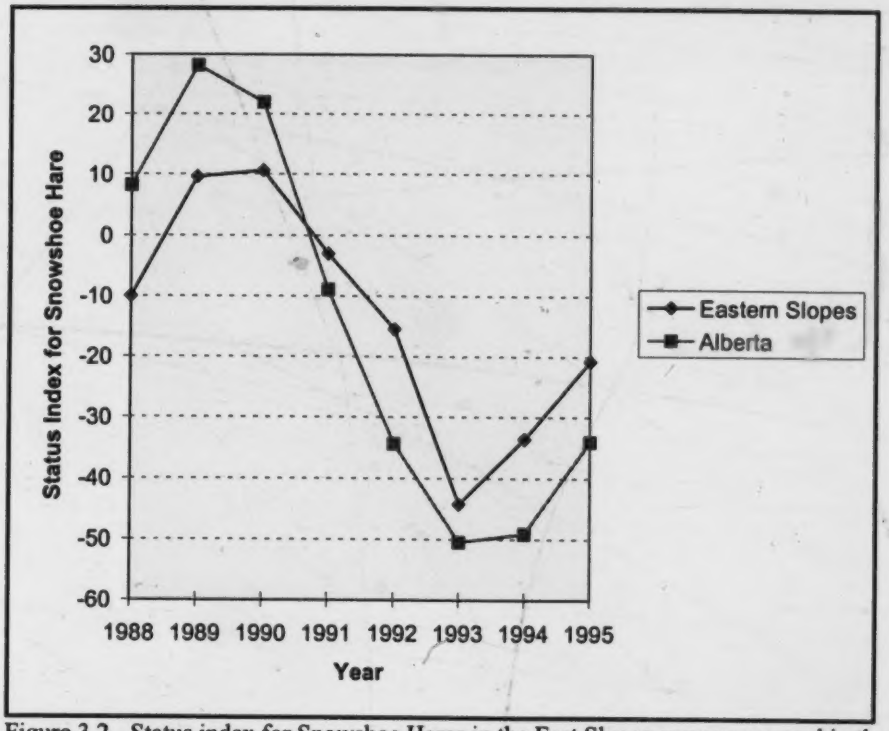

Figure 3.2 - Status index for Snowshoe Hares in the East Slopes survey area, and in the province of Alberta (1988-1995).

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4.0 Northern Goshawk (*Accipiter gentilis*) Habitat Management in central Alberta

4.1 INTRODUCTION

This study is the first to examine the habitat requirements of Northern Goshawks in the Parkland and Boreal Forest Ecoregions of Alberta. At present, forest harvesting for logging, seismic exploration and agricultural development represents the major cause of anthropogenic disturbance for forest-dwelling animals in central Alberta (Clark 1988, Farr 1992, Thompson and Welsh 1993, Lieffers and Beck 1994). Investigations have identified that Northern Goshawks are vulnerable to habitat fragmentation in the vicinity of nest sites (Woodbridge 1988, Patla 1990, Woodbridge and Detrich 1994, Erdman *et al.* 1998), and are sensitive to disturbance during the nesting season (Fyfe and Olendorff 1976, McCarthy *et al.* 1989).

The habitat conservation methods suggested herein are conservative, and this reflects the current lack of information on the size and composition of home ranges for adult and immature Northern Goshawks in central Alberta, and on the response of Northern Goshawks to habitat fragmentation in the Parkland and Boreal Forest Ecoregions. The habitat conservation methods should be adopted as an interim minimum acceptable standard for wildlife management in the province of Alberta (see sections 4.2 and 4.4). Effective Northern Goshawk habitat management will require participation and cooperation by forest industry, and representatives from the federal and provincial governments, and could utilize local field-naturalists as a volunteer workforce. It is recognized that at present, the majority of forest management planning in central Alberta is based on remotely sensed information (i.e. forest inventory, hydrology information) that does not attempt to intensively sample forest conditions.

Interim management strategies for Northern Goshawk populations in central Alberta should be directed towards:

- conserving habitat for Northern Goshawks at the microsite level (active nest sites);
- conserving habitat for Northern Goshawks at the landscape level (future nest sites, and foraging areas around nest sites);
- educating resource management personnel and forestry workers on the value, function, and appearance of Northern Goshawks and other woodland raptors; and
- conducting further research.

4.2 NORTHERN GOSHAWK HABITAT CONSERVATION

4.2.1 Active Nest sites

Investigations from other parts of the North America have recommended a variety of techniques for conserving habitat at Northern Goshawk nest sites. These techniques should be employed by fish and wildlife, and forest management personnel in central Alberta to conserve individual Northern Goshawk nests that are encountered over the course of forest management planning, or forest harvesting operations.

Although their effectiveness remains largely untested, no-cut buffer zones have been recommended for ensuring the protection of Northern Goshawk nest areas (McCarthy *et al.* 1989, Nelson and Titus 1989, Reynolds 1989, Cline 1990). Over the range of Northern Goshawks in North America, a variety of sizes of areas have been recommended for nest site management (Table 4.1). These areas were set to approximate the area of intensive use by adult Northern Goshawks and fledged young during the breeding season, according to locations of plucking posts and roosts (Reynolds *et al.* 1982, Reynolds 1983, Kennedy 1988). Until information on Northern Goshawk home range requirements and response to habitat fragmentation becomes available (see section 4.4), a no-harvest buffer zone of 12 ha (200 m radius from nest) should be established around each active and alternate nest site in central Alberta. Logging and other activities (i.e. vehicular traffic, recreational activities) in the region immediately surrounding the nest buffer zone should be prohibited during the Northern Goshawk breeding season (Fyfe and Olendorff 1976, Postovit and Postovit 1987, McCarthy *et al.* 1989, Nelson and Titus 1989). My study identified that in central Alberta, the Northern Goshawk breeding season starts in early March, and continues to late August.

4.2.2 Nest Site Conservation

My study identifies that large (mean diameter at breast height (1.42 m) of nest trees = 30.0 cm ± 01.32 S.E.), tall (mean height of nest trees = 21.9 m ± 0.63 S.E.) deciduous (*Populus*) trees, with large primary branches at the base of the crown are used by Northern Goshawks for nesting in central Alberta. Northern Goshawk nest stands exhibit attributes associated with mature seral stages of deciduous-dominated (*Populus*-dominated) forest. Information on Northern Goshawk prey use and foraging tactics suggests that older age classes of forest are important Northern Goshawk foraging habitat in west-central Alberta. Investigations from other parts of the range of Northern Goshawk have found that the area immediately adjacent to a Northern Goshawk nest (post-fledging family area: 170 ha; Kennedy *et al.* 1994) provides critical hunting habitat during

the breeding season for adults and newly fledged young (Crocker-Bedford and Chaney 1988, Reynolds *et al.* 1992).

In order to provide habitat for future Northern Goshawk nest areas, and to ensure the provision of foraging habitat in association with nest areas, certain stands of deciduous-dominated mixedwood should be managed to attain mature and old forest attributes (Reynolds *et al.* 1982, Nyberg *et al.* 1987, Reynolds 1989, Squires and Ruggiero 1996). Characteristics that are associated with mature deciduous-dominated forest include: closed canopy, multiple canopy layers, canopy gaps, large standing and fallen dead trees, and multiple ages of trees (Mehl 1992, Moir 1992). Efforts in this regard include lengthening the timber harvest rotation for certain stands to allow them to develop structural characteristics required by wildlife species dependent on mature and older seral stages of forest (Hansen *et al.* 1991, Crocker-Bedford 1994, Squires and Ruggiero 1996). At present, the rotation length for deciduous-dominated mixedwood management in Alberta is 60 years (Henderson 1988). Logging is typically undertaken on a two-pass clear-cut system with cut-blocks ranging from 20-40 ha in size (Nietfeld and Stelfox 1992, Stelfox 1995). Mature trembling aspen dominated stands average 95 years of age in the Rocky Mountain region of the United States (Shepperd and Engelby 1983). At 100 years of age trembling aspen stands start to break up, and there is an increased component of conifer regeneration (Mueggler 1985, Telfer 1992). A timber harvest rotation of at least 110 years will allow the development mature trembling aspen forest, and formation of structural attributes (i.e. large trees, closed canopies, open understories) that are important for Northern Goshawk nesting and foraging areas. Until information on Northern Goshawk post-fledging movements, and home range size of becomes available (see section 4.4), the minimum area to be conserved for future Northern Goshawk nesting areas should be 170 hectares. Forest harvesting blocks should be arranged to ensure minimal isolation of Northern Goshawk nest areas from adjacent areas of mature and old seral stage forest (Kennedy 1988).

4.3 RAPTOR EDUCATION

An education program should be established to increase awareness of the appearance, importance and management concerns surrounding Northern Goshawk populations amongst wildlife managers, forestry workers, forest managers and the general public (Postovit and Postivit 1987, Hammond and Bradley 1992, Thompson and Welsh 1993). This approach has worked effectively within the forestry sector in Canada on issues such as provision for snag trees

(Alberta-Pacific Forest Industries 1996), and fisheries habitat (Milton and Towers 1991) during forest harvesting. Teaching packages on forest birds of prey (including overheads, slides, poster displays, and videotape media) could act as a base for the presentations. Efforts are currently underway to produce a guidebook for resource managers and the general public on boreal raptors, following the approach taken in recent publications on forest hawk species (Szuba and Bell 1991) and prairie raptors (Holroyd *et al.* 1995) . The Model Forest Program of Forestry Canada, and representatives from provincial and federal fish and wildlife agencies could become partners in the guidebook project, and could contribute funding from their collective agencies so that it could be expanded to include a discussion of all forest dwelling raptors in Canada.

4.4 RESEARCH RECOMMENDATIONS

4.4.1 Radio-telemetry

Radio-telemetry methods should be used to provide base data on the size and composition of home ranges for adult and immature Northern Goshawks in the breeding and non-breeding season. A variety of active (mist nets erected in front of a lure at the Northern Goshawk nest site: Bloom *et al.* 1992, Steenhof *et al.* 1994), and passive (bal-chatri traps, falling lid, and falling door traps with live bait: Berger and Hamerstrom 1962, Kenward and Marcstrom 1983) methods of capture have been developed for Northern Goshawks. The Northern Goshawks should be fitted with backpack radio transmitters in order to monitor their movements (Kenward 1987). Lessons on effective radiomonitoring techniques in mountainous terrain from other areas of North America could serve as a basis for a training program for radiomonitoring field assistants (Guetterman *et al.* 1991). To deal with poor radio signal readings due to the mobile hunting behaviour of the Northern Goshawks, and the predicted radio signal bounce in diverse terrain, a team of at least 3 researchers should be used. The team members should take radiotelemetry readings on the same bird simultaneously while in radio contact with one another (Kenward 1987, Guetterman *et al.* 1991). In the northern part of their range, Northern Goshawks exhibit eruptive migrations in years of low abundance of primary prey species (Mueller *et al.* 1977). In order to monitor non-breeding movement patterns of Northern Goshawks and nest site fidelity, satellite radio-telemetry may be required (Duncan and Kirk 1994, Fuller *et al.* 1995).

4.4.2 Macrohabitat Selection

The macrohabitat conditions associated with Northern Goshawk nests and nest areas should be quantified by describing the placement of Northern Goshawk nests relative to landscape features,

and by describing the habitat conditions in Northern Goshawk nest areas. Variables to be included in this analysis should be:

- those that were found to influence *Accipiter* nest placement in other parts of North America: distance to water, distance to nearest roadway, distance to nearest opening, and type of opening (Falk and Stauffer 1989, Bosakowski *et al.* 1992, Bosakowski and Speiser 1994);
- those characteristics of macrohabitat that have been identified as having the strongest influence on *Accipiter* nesting habitat selection: interspersion of cover types, area of the habitat patch (Reynolds *et al.* 1982, Bosakowski *et al.* 1992, Schaffer *et al.* 1996); and
-those descriptors of macrohabitat patches that are used in published studies of habitat fragmentation: perimeter to area ratio, and index of patch isolation (Forman and Godron 1986, Turner 1989, Harrison and Fahrig 1995).

Additional information can be obtained by evaluating the composition of the nesting habitat at certain distances from the Northern Goshawk nest (Ripple *et al.* 1991, Hunter *et al.* 1995, Kimmel 1995).

4.4.3 Nest Monitoring

A monitoring program should be established to evaluate the effects of forestry operations on Northern Goshawk nest occupation and productivity (Robinson 1989). A nest monitoring program developed for Cooper's Hawk and Red-shouldered Hawk (*Buteo lineatus*) populations in Ontario (Szuba 1990) could be used as a guide for the nest monitoring protocols. Monitoring should be conducted as part of a long term study and will involve the direct manipulation of the habitat conditions around raptor nest sites by forest harvesting, with nest location work and productivity monitoring (Szuba 1990). The area of no-harvest buffer zones around Northern Goshawk nests could be modified to reflect the findings on minimum habitat conditions from nest site monitoring. Raptor banders could make yearly visits to nest sites to band Northern Goshawks, and to provide data on nest productivity. The use of colour bands by raptor banders could aid in the investigation of nest site fidelity (Detrich and Woodbridge 1994, Reynolds *et al.* 1994).

4.5 CONCLUSIONS

This study has gathered valuable information to contribute towards the conservation of Northern Goshawks and other wildlife that uses old forest. Cooperation between wildlife managers and forestry companies will ease habitat conservation. Further research will provide information for the refinement of management recommendations.

Table 4.1 - Recommended management area for provision for Northern Goshawk nest sites.

Location	Area (ha.)	Radius (m)	Source
United States	50.0 - 80.0	400.0 - 500.0	Jones 1979
Oregon	8.0	160.0	Reynolds *et al.* 1982
western United States	8.0	160.0	Reynolds 1983
New Mexico	20.0	250.0	Kennedy 1988
Arizona	>8.0	>160.0	Crocker-Bedford and Chaney 1988
New Hampshire	50.0	400.0	Lanier and Foss 1989
California	50.0	400.0	McCarthy *et al.* 1989
southwestern United States	12.0	200.0	Reynolds *et al.* 1992
New Mexico	10.0	180.0	Kennedy *et al.* 1994

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Appendix 1
Vegetation variables recorded during Northern Goshawk nest area vegetation surveys.

1) Location
2) Tree Species
3) Tree Type
    - T - Tree
    - S - Stub
    - N - Snag
4) Diameter at breast height of nest tree (cm)
5) Lean (in degrees)
6) Tree Height (m)
7) Crown Base (m)
8) Condition
    - 0 - Healthy
    - 1 - Leaf/Needle Loss
    - 2 - Dieback
9) Damage
    - 0 - None
    - 1 - Insects
    - 2 - Falling/breakage
    - 3 - Animal
    - 4 - Other
10) Cavities
11) Nest Height (m)
12) Direction/Exposure (in degrees)
13) Distance from trunk (m)
14) Crown density
15) Nest Type
16) Nest Construction Materials
17) Nest Size
18) Flight Corridor
    - 0 - Absent
    - 1 - Present
19) Distance to Clearing (m)
20) Additional Comments.

Appendix 1 (continued)
Vegetation variables recorded during Northern Goshawk nest area vegetation surveys.

1) Site Position - Macro
- 1 - Apex
- 2 - Upper Slope
- 3 - Middle Slope
- 4 - Lower Slope
- 5 - Valley Floor
- 6 - Plain
- 7 - Plateau

2) Site Position - Meso
- 1 - Crest
- 2 - Upper Slope
- 3 - Middle Slope
- 4 - Lower Slope
- 5 - Toe
- 6 - Depression
- 7 - Level

3) Surface Shape
- 1 - Straight
- 2 - Concave
- 3 - Convex

4) Soil Drainage
- 1 - Rapid
- 2 - Moderate
- 3 - Poor

5) Flood Hazard
- 1 - No hazard
- 2 - Rare
- 3 - May be expected
- 4 - Frequent

6) Slope (in degrees)
7) Aspect (in degrees)
8) Tree Height for 5 dominant overstory trees
9) Number of canopy layers
10) Dominant species in canopy
11) Dominant species in subcanopy
12) Dominant sapling species
13) Shrub coverage (%) in height classes:
>2.5 m, 1-2.5 m, <1 m
14) Herb coverage (%)
15) Grass/Sedge coverage (%)
16) Litter coverage (%)
17) Mineral coverage (%)
18) Moss coverage (%)
19) Lichens/Fungi coverage (%)
20) Downed Wood coverage (%)
21) Total Canopy Closure (%)
22) Number of Seedlings
23) Tree Description
a) Tree Species
b) Tree Type
- T - Tree
- S - Stub
- N - Snag

c) Distance of tree to plot centre (m)
d) Diameter at breast height of tree (cm)
e) Lean (in degrees)
f) Condition of trees
- 0 - Healthy
- 1 - Leaf/Needle Loss
- 2 - Dieback

g) Condition of Snags/Stubs
- 1 - Fresh/Recently Dead
- 2 - Hard/Dead a short time
- 3 - Hard/Dead a few years
- 4 - Hard/Many years dead
- 5 - Soft
- 6 - Decomposed

g) Damage
- 0 - None
- 1 - Insects
- 2 - Falling/breakage
- 3 - Animal
- 4 - Other

h) Animal Cavities
- 0 - None
- 1 - Present

24) Dead and Downed Wood
a) log length (m)
b) log base (cm)
c) log tip (cm)
d) log condition
1- Fresh
- 2 - Hard
- 3 - Soft
- 4 - Rotten or Punky
- 5 - Becoming part of the ground.

Appendix 2

Search effort for Northern Goshawk territories on the Foothills Model Forest - 1995.

Method	Date	Area (ha.)	Observations
Silent Search	March 30/95	10.0	1 Northern Pygmy Owl (*Glaucidium gnoma*)
			2 Golden Eagles (*Aquila chrysaetos*)
Silent Search	April 18/95	15.8	none
Silent Search	April 19/95	4.0	none
Silent Search	April 19/95	1.0	3 Red-tailed Hawks (*Buteo jamaicensis*)
Silent Search	April 20/95	20.0	none
Silent Search	April 21/95	7.5	none
Silent Search	April 22/95	11.8	none
Silent Search	May 13/95	5.0	none
Silent Search	May 17/95	16.0	1 Northern Harrier (*Circus cyaneus*)
			1 Golden Eagle (*Aquila chrysaetos*)
			1 Sharp-shinned Hawk (*Accipiter striatus*)
			1 American Kestrel (*Falco sparverius*)
			1 Merlin (*Falco columbarius*)
Silent Search	May 18/95	75.0	none
Silent Search	May 19/95	2.5	1 Red-tailed Hawk (*Buteo jamaicensis*)
Silent Search	May 19/95	5.0	none
Silent Search	May 19/95	10.0	none
Silent Search	May 22/95	18.8	2 stick nests
Silent Search	May 24/95	50.0	none
TOTAL		252.4	
Broadcast Surveys	June 2/95	162.6	none
Broadcast Surveys	June 3/95	70.7	none
Broadcast Surveys	June 9/95	70.7	1 Northern Goshawk (*Accipiter gentilis*)
Broadcast Surveys	June 22/95	120.1	none
Broadcast Surveys	June 23/95	127.3	none
Broadcast Surveys	June 28/95	63.6	none
TOTAL		615.0	

Appendix 2 (continued)
Search effort for Northern Goshawk territories on the Foothills Model Forest - 1996.

Method	Date	Area (ha.)	Observations
Silent Search	Feb 8/96	538.0	1 stick nest
Silent Search	Feb 20/96	314.0	2 stick nests
			1 Merlin (*Falco columbarius*)
Silent Search	Mar 5/96	314.0	2 stick nests
Silent Search	Mar 8/96	314.0	1 stick nest
			1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Mar 13/96	29.0	none
Silent Search	Mar 19/96	4.8	none
Silent Search	Mar 21/96	270.0	1 stick nest
			1 Red-tailed Hawk (*Buteo jamaicensis*)
Silent Search	Mar 23/96	60.3	1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Apr 5/96	4.8	none
Silent Search	Apr 6/96	18.0	none
Silent Search	Apr 11/96	13.0	1 Northern Hawk Owl (*Surnia ulula*)
Silent Search	Apr 15/96	19.3	none
Silent Search	Apr 16/96	40.0	none
Silent Search	Apr 16/96	33.3	none
Silent Search	Apr 19/96	2.0	1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Apr 21/96	18.0	none
Silent Search	Apr 26/96	5.4	none
Silent Search	Apr 26/96	39.7	none
Silent Search	May 3/96	40.9	none
Silent Search	May 8/96	9.6	1 Merlin (*Falco columbarius*)
Silent Search	May 15/96	42.3	1 Red-tailed Hawk (*Buteo jamaicensis*)
			1 Golden Eagle (*Aquila chrysaetos*)
			1 Northern Goshawk (*Accipiter gentilis*)
			1 Unidentified raptor
Silent Search	May 16/96	2.0	2 stick nests
Silent Search	May 16/96	11.2	1 stick nest
Silent Search	May 17/96	15.8	none
Silent Search	May 21/96	27.5	1 Sharp-shinned Hawk (*Accipiter striatus*)
Silent Search	Jun 3/96	105.0	1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Jun 5/96	72.0	none
Silent Search	Jun 6/96	6.4	1 Red-tailed Hawk (*Buteo jamaicensis*)
			2 stick nests
Silent Search	Jun 8/96	22.5	1 Northern Goshawk (*Accipiter gentilis*)
			1 stick nest
Silent Search	Jun 10/96	8.0	1 Red-tailed Hawk (*Buteo jamaicensis*)
Silent Search	Jun 11/96	10.1	1 stick nest
Silent Search	Aug 25/96	10.0	2 stick nests
TOTAL		**2421.0**	
Broadcast Surveys	Jun 14/96	70.7	none
TOTAL		**70.7**	

Appendix 3

Stick nest vegetation and occupancy for nests on the Foothills Model Forest.

Nest #	Nest Tree Species[a]	Year Occupied	Species Nesting
1	Aw	n/a	n/a
2	Aw	1994,1996	Northern Goshawk (*Accipiter gentilis*)
3	Aw	1995	Red-tailed Hawk (*Buteo jamaicensis*)
4	Aw	1995	Northern Goshawk (*Accipiter gentilis*)
5	Aw	1995	Northern Goshawk (*Accipiter gentilis*)
6	Aw	1996	Great Gray Owl (*Strix nebulosa*)
7	Aw	n/a	n/a
8	Aw	n/a	n/a
9	Aw	1995	Common Raven (*Corvus corax*)
10	Aw	n/a	n/a
11	Aw	1996 1995	Red-tailed Hawk (*Buteo jamaicensis*) Great Gray Owl (*Strix nebulosa*)
12	Aw	1995	Common Raven (*Corvus corax*)
13	Pl	n/a	n/a
14	Pl	1995	Common Raven (*Corvus corax*)
15	Sw	n/a	n/a
16	Aw	1996	Red-tailed Hawk (*Buteo jamaicensis*)
17	Aw	n/a	n/a
18	Pl	n/a	n/a
19	Aw	n/a	n/a
20	Aw	1995	Great Horned Owl (*Bubo virginianus*)
21	Aw	n/a	n/a
22	Aw	1995	Northern Goshawks (*Accipiter gentilis*)
23	Aw	n/a	n/a
24	Aw	n/a	n/a
25	Aw	n/a	n/a
26	Aw	n/a	n/a
27	Aw	1995	Common Raven (*Corvus corax*)
28	Aw	1996	Common Raven (*Corvus corax*)
29	Aw	n/a	n/a
30	Aw	n/a	n/a
31	Aw	1996	Red-tailed Hawk (*Buteo jamaicensis*)
32	Aw	n/a	n/a
33	Aw	1996	Common Raven (*Corvus corax*)
34	Aw	1996	Common Raven (*Corvus corax*)
35	Aw	1995	Common Raven (*Corvus corax*)
36	Aw	1996	Common Raven (*Corvus corax*)
37	Pl	1996	Common Raven (*Corvus corax*)
38	Aw	1996	Common Raven (*Corvus corax*)
39	Pb	1996	Northern Goshawk (*Accipiter gentilis*)
40	Aw	1996	Common Raven (*Corvus corax*)
41	Aw	n/a	n/a
42	Aw	n/a	n/a
43	Aw	n/a	n/a
44	Aw	1993, 1994, 1995	Common Raven (*Corvus corax*)
45	Aw	1995	Common Raven (*Corvus corax*)
46	Aw	n/a	n/a
47	Aw	1995	Great Gray Owl (*Strix nebulosa*)
48	Aw	n/a	n/a
49	Aw	1996	Common Raven (*Corvus corax*)
50	Aw	n/a	n/a
51	Aw	n/a	n/a
52	Aw	1996	Northern Goshawk (*Accipiter gentilis*)
53	Aw	1996	Common Raven (*Corvus corax*)
54	Aw	n/a	n/a
55	Aw	1996	Red-tailed Hawk (*Buteo jamaicensis*)
56	Fd	1995 1996	Common Raven (*Corvus corax*) Great-Horned Owl (*Bubo virginianus*)
57	Sw	1995, 1996	Great-Horned Owl (*Bubo virginianus*)

[a] - Nest Tree Species - Aw - Trembling Aspen (*Populus tremuloides*), Pb - Balsam Poplar (*Populus balsamifera*), Pl - Lodgepole Pine (*Pinus contorta*), Fd - Douglas Fir (*Pseudotsuga menziesii*).

Appendix 4 - Northern Goshawk nest tree characteristics (nests active 1952-1997).

Nest	Tree Species	Year Occupied	Nest tree DBH (cm)	Nest tree ht. (m)	Nest ht. (m)	% Nest Height	Nest Placement	# of Supporting branches	# of Canopy Layers	Flight Corridor (Present/Absent)
A1	*Populus tremuloides*	1994, 1996, 1997	32.5	24.9	15.3	61.4	Primary branch fork at crown base	5	2	Present
A2	*Populus tremuloides*	1995	25.3	21.0	15.3	72.9	Primary branch fork at crown base	5	2	Present
B1	*Populus tremuloides*	1995	24.4	19.5	12.0	61.5	Primary branch fork at crown base	6	2	Present
C1	*Populus tremuloides*	1995	39.4	24.0	15.9	66.3	Primary branch fork in tree crown	5	3	Present
D1	*Populus balsamifera*	1996	35.6	25.8	14.7	57.0	Primary branch fork at crown base	3	2	Present
E1	*Populus tremuloides*	1996	37.3	28.0	14.6	52.0	Primary branch fork at crown base	6	2	Present
F1	*Populus tremuloides*	1995	25.2	25.8	16.2	62.8	Primary branch fork at crown base	4	1	Present
F2	*Populus tremuloides*	1996	25.9	20.7	14.1	68.1	Primary branch fork at crown base	5	1	Present
F3	*Populus tremuloides*	1994	26.2	19.8	17.4	87.9	Primary branch fork at crown base	5	2	Present
F4	*Populus tremuloides*	1997	27.1	19.5	14.7	75.4	Primary branch fork at crown base	3	2	Present
G1	*Populus tremuloides*	1993	38.9	21.0	10.8	51.4	Primary branch fork in tree crown	5	2	Present
H1	*Populus tremuloides*	1994, 1995	33.0	24.9	16.5	66.3	Primary branch fork at crown base	5	2	Present
I1	*Populus tremuloides*	1996	30.8	21.0	15.0	71.4	Primary branch fork at crown base	5	2	Present
I2	*Populus tremuloides*	1995	34.6	21.0	12.9	61.4	Primary branch fork at crown base	6	2	Present
I3	*Populus tremuloides*	1997	23.0	18.3	13.8	75.4	Primary branch fork in tree crown	3	2	Present
J1	*Populus tremuloides*	1994	21.2	21.0	15.0	71.4	Primary branch fork at crown base	3	2	Present
J2	*Populus tremuloides*	1991,1993	25.1	18.0	13.0	72.2	Primary branch fork at crown base	6	2	Present
K1	*Populus balsamifera*	1996	28.0	21.0	13.8	65.7	Primary branch fork at crown base	4	2	Present
K2	*Populus tremuloides*	1993	26.9	22.2	13.5	60.8	Primary branch fork at crown base	4	1	Present
K3	*Populus tremuloides*	1995								

Appendix 4 (continued) - Northern Goshawk nest tree characteristics (nests active 1952-1997).

Nest	Tree Species	Year Occupied	Nest tree DBH (cm)	Nest tree ht. (m)	Nest ht. (m)	% Nest Height	Nest Placement	# of Supporting branches	# of Canopy Layers	Flight Corridor (Present/Absent)
L1	*Populus tremuloides*	1996	30.7	23.4	18.3	78.2	Primary branch fork at crown base	4	2	Present
L2	*Populus tremuloides*	1997	29.4	21.0	16.2	77.1	Primary branch fork at crown base	7	2	Present
M1	*Populus tremuloides*	1997	33.3	24.3	15.0	61.7	Primary branch fork in tree crown	3	2	Present
N1	*Populus tremuloides*	1997	33.8	19.8	15.0	75.8	Primary branch fork in tree crown	4	2	Present
O1	*Pinus contorta*	1997	16.1	14.4	10.8	75.0	Primary branch fork at crown base	3	2	Present
P1	*Populus tremuloides*	1996	46.2	27.4	21.8	79.6	Primary branch fork in tree crown	4	2	Present
P2	*Populus tremuloides*	1997								
Q1	*Populus balsamifera*	1952			17.4*					
R1	*Populus balsamifera*	1953			11.6*					
S1	*Populus tremuloides*	1953			9.2*					
T1	*Populus tremuloides*	1956			9.2*					
U1	*Betula papyrifera*	1957			10.7*					
V1	*Populus tremuloides*	1965			10.7*					
W1	*Populus tremuloides*	1970			12.2*					
W2	*Populus tremuloides*	1971			15.3*					
X1	*Populus tremuloides*	1971			9.2*					
Y1	*Populus tremuloides*	1988			13.7*					
Z1	*Populus tremuloides*	1988			12.2*					
AA1	*Populus tremuloides*	1988, 1989			13.7*					
AA2	*Populus balsamifera*	1990			12.2*					
AB1	*Populus tremuloides*	1989.1991								
AB2	*Populus tremuloides*	1990								
AC1	*Populus tremuloides*	1994								
AD1	*Populus tremuloides*	1995								
AE1	*Picea glauca*	1991								
Mean**			30.0 ± 1.32 SE	21.9 ± 0.63 SE	14.8 ± 0.46 SE	68.4 ±1.78 SE		4.00 ±0.23 SE	1.92 ±0.08 SE	

* - Ocular estimate of height (conversion from imperial scale).

** - Ocular estimates of height not included in calculation of mean height.

Appendix 5 - Weights of Northern Goshawk prey in the western study area.

Prey Species	Individual Biomass (g)[a]
MAMMALS	
Snowshoe Hare *(Lepus americanus)*	1435.00
Snowshoe Hare (immature) *(Lepus americanus)*	717.50
Red Squirrel *(Tamiasciurus hudsonicus)*	216.82
Bushy-tailed Woodrat *(Neotoma cinerea)*	335.10
Meadow Vole *(Microtus pennsylvanicus)*	31.00
Pika *(Ochotona princeps)*	138.05
Unidentified microtine	31.00
BIRDS	
Blue Grouse *(Dendragapus obscurus)*	1039.50
Spruce Grouse *(Falcipennis canadensis)*	474.00
Ruffed Grouse *(Bonasa umbellus)*	576.50
Pileated Woodpecker *(Dryocopus pileatus)*	287.00
Northern Flicker *(Colaptes auratus)*	111.00
Three-toed Woodpecker *(Picoides tridactylus)*	65.65
Gray Jay *(Perisoreus canadensis)*	71.10
American Robin *(Turdus migratorius)*	77.30
Hermit Thrush *(Catharus guttatus)*	31.00
Black-throated Green Warbler *(Dendroica virens)*	8.80
Unidentified passerine	47.05
Unidentified bird	274.19

[a] - based on information found in Steenhof 1983, Dunning 1984, Smith 1993, and M. Wheatley, University of Alberta, unpublished data.

Appendix 6 - Weights of Northern Goshawk prey in the eastern study area.

Prey Species	Individual Biomass (g)[a]
MAMMALS	
Snowshoe Hare *(Lepus americanus)*	1435.00
Richardson's Ground Squirrel *(Spermophilus richardsonii)*	346.00
Red Squirrel *(Tamiasciurus hudsonicus)*	216.82
BIRDS	
Green-winged Teal *(Anas crecca)*	341.00
Green-winged Teal (immature) *(Anas crecca)*	170.50
Blue-winged Teal *(Anas discors)*	385.50
Mallard *(Anas platyrhynchos)*	1177.50
Mallard (immature) *(Anas platyrhynchos)*	588.80
Northern Shoveler (immature) *(Anas clypeata)*	613.00
Sharp-shinned Hawk *(Accipiter striatus)*	138.50
Ruffed Grouse *(Bonasa umbellus)*	576.50
Yellow-bellied Sapsucker *(Sphyrapicus varius)*	50.30
Blue Jay (immature) *(Cyanocitta cristata)*	43.40
Black-billed Magpie (immature) *(Pica pica)*	88.75
American Robin *(Turdus migratorius)*	77.30
Unidentified Duck	634.70
Unidentified Duck (immature)	379.70
Catharus spp.	30.90
Unidentified bird	353.09

[a] - based on information found in Steenhof 1983, Dunning 1984, Smith 1993, and M. Wheatley, University of Alberta, unpublished data.

Appendix 7 - Additional Northern Goshawk prey use information from central Alberta, compiled from Pileated Woodpecker study, sightings and records of raptor banders.

Prey Species	Frequency in Diet
MAMMALS	**17**
Snowshoe Hare (*Lepus americanus*)	8
Richardson's Ground Squirrel (*Spermophilus richardsonii*)	5
Red Squirrel (*Tamiasciurus hudsonicus*)	2
Muskrat (*Ondratra zibethica*)	1
Unidentified microtine	1
BIRDS	**27**
Sharp-shinned Hawk (*Accipiter striatus*)	1
Gray Partridge (*Perdix perdix*)	2
Ruffed Grouse (*Bonasa umbellus*)	7
Great Gray Owl (*Strix nebulosa*) (immature)	2
Northern Saw-whet Owl (*Aegolius acadicus*)	1
Pileated Woodpecker (*Dryocopus pileatus*)	8
American Crow (*Corvus brachyrhynchos*)	1
Varied Thrush (*Ixoreus naevius*)	1
European starling (*Sturnus vulgaris*)	1
Domestic chicken (*Gallus gallus*)	2
Domestic turkey (*Meleagris gallopavo*) (immature)	1
Total PREY	**44**

Appendix 8 - Northern Goshawk diet composition during the breeding season from published literature (adapted from Squires and Reynolds 1997).

Location	% of Mammalian Prey (% Biomass)	% of Avian Prey (% Biomass)	% of Reptilian Prey (% Biomass)	Source
UNITED STATES				
Alaska	78 (90)	21 (10)		Zachel 1985[1]
Arizona	76 (94)	24 (6)		Boal and Mannan 1994[3]
Arizona	62	38		Reynolds et al. 1994[1,2]
California	32	68		Bloom et al. 1986[3]
California	31	69		Schnell 1958[1]
Connecticut	59	39	2	Root and De Simone 1978[1,2,3]
Nevada	67	32		Younk and Bechard 1994[1]
New Mexico, Arizona	9	91		Snyder and Wiley 1976[3]
New Mexico	49	51		Kennedy 1991[1]
New York	39	61		Grzybowski and Eaton 1976[3]
New York, Pennsylvania	39	61		Meng 1959[1,2]
Oregon	42	59		Bull and Hohmann 1994[3]
Oregon	45	55		Reynolds and Meslow 1994[1,2]
Utah	82	18		Lee 1981[1,2]
CANADA				
Yukon	76 (86)	24 (13)		Doyle and Smith 1994[3]
SWEDEN	21 (15)	79 (85)		Widen 1982[3]

1 - Pellet analysis.
2 - Prey remains.
3 - Direct Observation.